FINAL

Background Summary Report

Reclamation Reuse for Groundwater Recharge

Volume Two • Report

City of San Jose • Santa Clara Valley Water District

CH2M HILL
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PROPERTY OF SANTA CLARA VALLEY
WATER DISTRICT
5750 Almaden Expressway
San Jose, California [illegible]

Final

Background Summary Report
Reclamation Reuse for Groundwater Recharge

Volume 2
Report

Prepared for
City of San Jose
and
Santa Clara Valley Water District

Prepared by
CH2M HILL

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Acronyms

ac-ft	acre foot
ac-ft/yr	acre foot per year
ASR	Aquifer Storage and Recovery
BAAQMD	Bay Area Air Quality Management District
BAC	biologically active carbon
BOD	biochemical oxygen demand
CCWA	Clayton County Water Authority
CDO	Cease and Desist Order
cfs	cubic feet per second
CVP	Central Valley Project
DBP	disinfection by-products
DOHS	Department of Health Services
DPRDP	Direct Potable Reuse Demonstration Plant
DWR	Department of Water Resources
EDR	electrodialysis reversal
EPA	Environmental Protection Agency
g/l	micrograms per liter
GAC	granular activated carbon
GC	gas chromatograph
GCMS	gas chromatograph mass spectrometer
gpm/sf	gallons per minute per square foot
hp	horsepower
kW-hr	kilowatt hour
MCL	maximum contaminant level
mg/l	miligrams per liter
mgd	million gallons per day
NPDES	National Pollutant Discharge Elimination System
NTU	nephclometric turbidity unit
O&M	Operation and Maintenance
OCWD	Orange County Water District
PAC	powdered activated carbon
PCB	polychlorinated biphenol
pfu/gal	plaque forming units per gallon
PPB	parts per billion
psi	pounds per square inch
RO	reverse osmosis
RPHL	recommended public health levels
RWQCB	Regional Water Quality Control Board
SBDA	South Bay Dischargers Authority
SCVWD	Santa Clara Valley Water District
SDLAC	Sanitation Districts of Los Angeles County
SJ/SC WPCP	San Jose/Santa Clara Water Pollution Control Plant

SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
THM	trihalomethane
THMFP	trihalomethane formation potential
TKN	total kjeldahl nitrogen
TOC	total organic carbon
UOSA	Upper Occoquan Sewge Authority
UV	ultraviolet
WCRWSA	West Coast Regional Water Supply Authority

Chapter 1
Groundwater Recharge Reclamation Program

Chapter 1

Groundwater Recharge Reclamation Program

Introduction

This chapter includes an introduction and a presentation of background information on the potential groundwater recharge of reclaimed water in the Santa Clara Valley. This Background Summary Report is intended to identify the major opportunities, the major issues and constraints, the overall system requirements, and a future course of action for groundwater recharge reclamation.

The project was originally conceived in 1989 when the City conducted a reconnaissance investigation of reclamation opportunities in Northern Santa Clara County (Reconnaissance Investigation) (Reference 1-1). The resulting Reconnaissance Investigation report, completed in March 1990, was the first step in identifying the beneficial reuse of highly treated wastewater from the San Jose/Santa Clara Water Pollution Control Plant (SJ/SC WPCP). Two types of reclamation and reuse were identified: nonpotable and groundwater recharge. Although both types appeared feasible, the implementation issues, schedules, and costs were substantially different. Therefore, two separate projects were identified. This Background Summary Report is the next step for developing groundwater recharge reclamation.

The City of San Jose (City) and the Santa Clara Valley Water District (SCVWD) have jointly funded this Reclamation Reuse Groundwater Recharge Background Summary Report. This report updates the groundwater recharge aspects of the Reconnaissance Investigation and includes information initially distributed as technical memoranda covering previous reuse projects and health studies (Chapter 2), aquifer recharge (Chapter 3), demonstration plant influent quality (Chapter 5), regulatory treatment requirements (Chapter 5), and treatment residuals (Chapter 7). This report also incorporates comments made by the SCVWD, the City, and a Blue Ribbon Committee review. New or modified text is italicized in this draft report.

Background

The Reconnaissance Investigation identified two principal benefits associated with nonpotable and groundwater recharge reclamation:

- Reduction of wastewater discharge and any associated conversion of salt marsh to either a fresh or brackish water marsh.
- Provision of a supplemental, reliable water supply source.

Reclamation provides a unique opportunity to optimize the solutions to some of the issues facing both the City in addressing the flow reduction from the SJ/SC WPCP and the SCVWD in addressing reliable supplemental water supplies. Reclamation presents such a solution while making use of a valuable resource, highly treated effluent.

Development of a groundwater recharge reclamation and reuse program for the Santa Clara Valley requires an understanding of wastewater issues, water supply issues, the results of previous investigations, the needs of the various agencies, the relevant physical characteristics of the study area, the quality of water to be reclaimed, and the facilities available. Given this background, reclamation opportunities can be identified and treatment/conveyance facilities conceptualized.

The City is not responsible for water supply; that role belongs to SCVWD and to the several private and public water purveyors. Even so, the City has a strong interest in maintaining and providing additional supplies within the limits defined in various planning documents. This interest is, in part, based on the need to ensure a water supply that will support planned growth, reduce sensitivity to decreased quantities of local and imported water supplies during drought years, and ensure that ample supplies are available, which will prevent overdrafting and potential subsequent ground subsidence. The City's interest is also related to wastewater NPDES issues, as discussed in the next section.

Wastewater Issues

The SJ/SC WPCP reliably treats and discharges a very high quality effluent to South San Francisco Bay (South Bay). However, because this area is environmentally sensitive, additional measures are necessary to further protect the area influenced by the plant's discharge. Reclamation effectively addresses flow by reducing the quantity of effluent that is discharged.

The Basin Plan developed in the early 1970s prohibits wastewater discharge south of the Dumbarton Bridge. In an effort to gain an exception to the Basin Plan by demonstrating a net environmental benefit, the SJ/SC WPCP participated in the 5-year South Bay Dischargers Authority (SBDA) water quality monitoring study. Based on the study, the Regional Water Quality Control Board (RWQCB) staff has determined that water quality enhancement occurs, due to localized increase of receiving water dissolved oxygen and the flushing effects of the discharge. The effects enhance the beneficial uses of noncontact recreation, estuarine habitat, and sport fishing. However, the RWQCB staff denied the request for exception based on the assertion that the plant discharge has been associated with conversion of salt marsh to either fresh or brackish water marsh. The salt marsh is habitat for two rare and endangered species, the California clapper rail and the salt marsh harvest mouse. Therefore, the RWQCB, as part of National Pollutant Discharge Elimination System (NPDES) Permit No. 89-012, determined that the SJ/SC WPCP's discharge location is in nonconformance with the Basin Plan Policy and the Bays and Estuaries Policy.

The RWQCB's Cease and Desist Order (CDO) No. 89-013 states that the SJ/SC WPCP is responsible for the conversion of salt marsh between 1970 and 1985. To gain an exception to the Basin Plan prohibitions, the CDO states that mitigation for the loss of salt marsh must be implemented. The CDO specifies that eligible mitigation projects include creation or enhancement of salt marsh, reclamation that reduces annual average flows to 1970 levels (a required annual average flow reduction of up to 45 million gallons per day [mgd]), relocation of the plant's discharge (construction of a deep-water outfall) that will result in a projected net increase of salt marsh habitat, or a combination of options to result in a net increase of habitat.

Subsequently, the State Water Resources Control Board (SWRCB), Order WQ 90-5 (October 4, 1990), required the RWQCB to amend the discharge permit to limit effluent flows to 120 mgd. This was done in an effort to halt future marsh conversion. The RWQCB has interpreted the 120-mgd flow limit to be the average dry weather flow measured during the lowest 3-month flow period from May 1 through October 31. The low flow period for the SJ/SC WPCP, however, is generally the period starting in either March or April and extending for 3 months. Within the limits of the RWQCB's definition, the plant's low flow period is May, June, and July. The average plant flows in the May-July period are approximately 2 mgd less than in the June-July period. The City of San Jose subsequently developed and submitted an action plan in response to the pending flow limit. The 1991 action plan contains a number of elements intended to fulfill the intent of the SWRCB order. Two of the elements are a 9- to 10-mgd nonpotable reclamation project and a 50- to 60-mgd potable reclamation project. The RWQCB accepted the action plan as a viable alternative to the flow cap. The nonpotable reclamation project has developed into a 50- to 60-mgd capacity, while the size of the potable reclamation project is still under consideration. The action plan will be updated to reflect current project capacities and schedules.

Water Supply Issues

Reclaimed water is increasingly being viewed as a very valuable resource. As a supplemental water supply, it is drought-resistant and falls under local control. Reclaimed water is, therefore, seen as an important component of SCVWD's water supply. Reclaimed water adds to the available supply for the County.

The SCVWD is the water wholesaler of the region and uses a variety of sources including local surface water, groundwater, and imported water to meet the water demands of its customers (purveyors). The water purveyors include public and private entities such as the City of San Jose, City of Santa Clara, City of Milpitas, San Jose Water Company, and Great Oaks Water Company. The major water supplies for Santa Clara County are as follows:

- Local water supply generated through storage of local rainfall and runoff

- Imported water supply purchased from the City of San Francisco through the Hetch Hetchy system
- Imported water supply purchased from the State of California through the South Bay Aqueduct system
- Imported water supply purchased from the U.S. Bureau of Reclamation through the San Felipe system

Approximately half of the raw water supply is from imported sources. Water imported from the state and federal projects, along with local surface runoff, is used to recharge the groundwater and supply the three water treatment plants. These three plants, Santa Teresa, Rinconada, and Penitencia, now have a combined capacity of 215 mgd. Imported water from Hetch Hetchy is piped directly to the local water retailer distribution systems. The groundwater recharge facilities were sized based on the available quantities of local surface supplies. Local water supplies include the water impounded in the various surface-water reservoirs, which is subsequently used for groundwater recharge, and the miscellaneous stream and subsurface flows that also recharge the groundwater. The reservoirs in the Santa Cruz Mountains are smaller and are often dry during the summer months. The Anderson and Coyote Reservoirs in the Diablo Range are larger and have substantial carryover storage capacity from one year to the next.

Although the SCVWD has done extensive planning to secure a reliable water supply, several factors show that reclaimed water will be a valuable supplemental water source. These factors include the uncertainty of obtaining the full contracted state and federal water project entitlements, the current drought, the variability of local supplies, the current Bay Delta hearings that may reallocate water rights for the preservation of fish and wildlife, and an increasing concern for the quality and reliability of Delta water. Reclaimed water will provide a relatively high quality, reliable, drought-resistant addition to the water supply of the County.

The SCVWD is preparing a system overview that identifies a number of possible sources of new water supplies, including conservation, water purchases and transfers, nonpotable reclamation, reservoir construction, groundwater recharge reclamation, and desalinization. Preliminary results indicate that SCVWD needs to develop new water supplies totaling approximately 15,000 acre-foot per year (ac-ft/yr) for its long-term water needs through the year 2020. These quantities are preliminary and will be updated as part of the 1992 system overview. During a critical dry period, the preliminary results have indicated that the SCVWD needs an additional 105,000 ac-ft/yr.

The limiting factor for groundwater recharge of reclaimed water as far as the City is concerned may be the minimum reclaimed water for groundwater recharge that the groundwater basin is able to store and is able to accept in a wet year, given the available local surface and imported supplies. The use of a guaranteed quantity of high-quality reclaimed water is considered a potential source for this required future water supply. The SCVWD has several concerns regarding the viability of recharging reclaimed water, and these include concern over the potential for contaminating the groundwater basin, concern regarding health effects reservations of public acceptance, high project cost, and impacts of the use of existing supplies. But because there are a number of unknowns with the other options, further definition of a groundwater recharge project is desirable.

Nonpoint Source Issues

Another reclamation objective is to reduce the amount of metals that enter the lower portion of the South Bay by decreasing the metals load in proportion to the wastewater flow diverted from the Bay. Groundwater recharge will directly impact metals in the Bay. These restrictions do affect options for treatment process of residual disposal, specifically reverse osmosis (RO) brine disposal. The quantity of metals entering the South Bay is related to potential toxicity to various aquatic organisms. Currently, there are two primary sources of heavy metal constituents: nonpoint sources, such as stormwater runoff, and point sources, such as discharge from the SJ/SC WPCP. A receiving water such as the South Bay has the ability to assimilate a given quantity of contaminants without degrading the beneficial uses. Each receiving water is unique, and thus its ability to assimilate contaminants is also unique. The assimilation capacity can be defined in terms of a waste load for each type of pollutant, such as metals. Waste loads can be set for individual metals and for the total of all metals.

Overall waste load allocations have not been set for the South Bay, but it is anticipated that they may be implemented, through actions of RWQCB, in the future. It is expected that the waste load allocation would have to be divided between point and nonpoint sources. The SCVWD is sponsoring work to determine the magnitude of existing nonpoint source loadings; site specific work has also been done for the SJ/SC WPCP, a point source, to determine the assimilative capacity of indicator organisms and is currently under review by the RWQCB. The results of this work may be used to set the total waste load allocation.

In anticipation of this allocation, the RWQCB has imposed very stringent requirements for discharge of metals on the SJ/SC WPCP and the two other wastewater treatment plants in the South Bay. Although these metals are present in the plant effluent at very low levels, these new requirements may eventually require that plant effluent metals discharged to the South Bay be further reduced. Implementation of a reclamation and reuse program could help improve discharge requirements associated with waste load allocations of metals from both point and nonpoint sources.

Previous Local Reclamation Investigations

Since 1978, a number of studies have been conducted on the reuse of reclaimed water in the north Santa Clara Valley. Most of these studies focused on nonpotable reclamation. The previous reclamation/reuse investigations include the following:

- Consoer, Townsend & Associates' study in June 1978 (CTA, 1978) of reclamation/reuse in the vicinity of the SJ/SC WPCP (Ref. 1-2)

- Brown and Caldwell's 1978 study (Brown and Caldwell, 1978) for the Santa Clara Valley Water District of reclamation/reuse in the Milpitas-North San Jose area (Ref. 1-3)

- Brown and Caldwell's 1980 study (Brown and Caldwell, 1980), which amended the 1978 study for San Jose, Milpitas, and Santa Clara (Ref. 1-4)

- CH2M HILL's December 1981 study (CH2M HILL, 1981) for the State Water Resources Control Board, entitled San Francisco Bay Regional Reuse Study (Ref. 1-5)

Each of these studies had a different focus; however, none resulted in a reclamation/reuse project being implemented. A detailed discussion of these previous reclamation/reuse investigations can be found in the 1989 Reconnaissance Investigation Report.

Need for Additional Studies

A number of factors have changed since the 1978-1981 period, which makes a current study of reclamation desirable. First, effluent water quality at the SJ/SC WPCP has improved since 1980, when the Brown and Caldwell 1980 study was completed. The advanced wastewater treatment facilities have been operating effectively and reliably for many years, which will certainly have an impact on potential users' interest in using the reclaimed water.

Second, water reclamation and reuse is practiced throughout the state to a greater extent than in the late 1970s, and regulatory agencies have become more comfortable with the use of reclaimed water from properly designed and operated direct filtration plants for a variety of irrigation and body contact uses.

Third, the use of reclaimed water for groundwater recharge has been studied extensively throughout the past decade. As a result of these studies, the state is now releasing preliminary criteria for review, on appropriate levels, of reclaimed water treatment for subsequent recharge into groundwater aquifers used as potable water supplies.

Finally, as summarized under the previous Wastewater and Water Issues sections, the City of San Jose action plan has identified groundwater reclamation as an alternative to meet the CDO and NPDES requirements for the SJ/SC WPCP, the SCVWD is interested in identifying additional water supply facilities, and both the City and SCVWD will need to address nonpoint source discharges in the future.

Description of Study Area

Santa Clara Valley is the study area for the Background Summary Report investigation of groundwater recharge reclamation opportunities. This study area, shown on Figure 1-1, is bounded on the west by Calabazas Creek and contains most of the urban development located in northern Santa Clara County. The major features related to reclamation are the SJ/SC WPCP, the agricultural area around the plant, the Bay, the creeks flowing into the Bay, the groundwater recharge facilities along the creeks, and the parks and other landscaped areas scattered throughout the area.

The SJ/SC WPCP is located at the southern end of the South Bay and is on the northern end of the study area. The WPCP treats essentially all the wastewater generated in the study area.

Three major streams, Coyote Creek, Guadalupe River, and Los Gatos Creek, bisect the study area, flowing north to South Bay. These streams are seasonally intermittent, although their streamflows are significantly influenced by releases from SCVWD facilities and current groundwater cleanup operations.

Hydrogeology

The hydrogeology is discussed further in Chapter 3, Aquifer Storage.

Subsidence

The groundwater basin is reported to have a very large capacity. This capacity was tapped by major wells for agricultural irrigation in the early 1900s and even more so beginning in about 1950 for urban needs, resulting in severe ground subsidence. Subsidence occurs when excessive amounts of water are removed from aquifers, increasing the effective stress on the various clay lenses, thus allowing the clay to compact. This subsidence is irreversible because clay does not rebound. The subsidence has increased flood potential and has caused damage to underground utilities, streets, and even buildings. The SCVWD efforts to recharge the basin have raised the groundwater elevation and have stopped subsidence. The primary concern of the SCVWD regarding pumpage in excess of recharge is the potential for reinitiating subsidence and the adverse consequences.

Surface Water Resources

Surface waterways within the planning area flow in a general northerly direction toward San Francisco Bay and drain the Diablo Range to the east and the Santa Cruz Mountains to the west. The major surface streams in this area are Coyote Creek, Guadalupe River, and Los Gatos Creek. Los Gatos Creek is a tributary to the Guadalupe River. Coyote Creek's drainage system is the most extensive in the county.

Flows in these surface streams are regulated by reservoirs upstream. Some of the reservoirs serve the dual functions of flood control and water conservation.

Water Demand and Supply

Water supplies, particularly local supplies, vary significantly from year to year. Based on the period from 1964 to 1977, the long-term average local supply countywide was estimated to be 231,000 acre-foot per year (ac-ft/yr). In addition, the SCVWD had contracted for 100,000 ac-ft/yr from the South Bay Aqueduct of the State Water Project (SWP) and 152,000 ac-ft/yr from the San Felipe Division of the Federal Central Valley Project (CVP). Also, the various cities had contracted for 60,000 ac-ft/yr from San Francisco's Hetch Hetchy Aqueduct with a plan to increase that to 90,000 ac-ft/yr. Finally, the SCVWD had planned for 12,000 ac-ft/yr of reclamation. The total water supply, therefore, was 550,000 ac-ft/yr, matching the projected demand.

Although previous planning efforts had projected supply that would meet demand, the supply was not based on actual dry year water availability that has occurred since 1977. For example, the local water supplies in North County in 1977 and in 1988 totaled less than 20,000 and 60,000 ac-ft/yr, respectively. Additionally, the SWP has developed a supply for only about half of its contracted deliveries and the CVP has major deficiencies in its conveyance capacity. Currently, the SCVWD has a 75 percent floor for municipal and industrial supplies from the CVP. In regard to the Hetch Hetchy system, the present aqueducts are now at capacity while supplies were reduced in 1988. Finally, the projected reclamation facilities have not been developed.

The SCVWD is currently updating its Master Plan, with preliminary results indicating that the SCVWD needs to develop new water supplies totaling approximately 15,000 ac-ft/yr for its long-term water needs through the year 2020. These quantities are preliminary and will be updated as part of the 1992 Master Plan revision. During a critical year the preliminary results indicate that the SCVWD needs an additional 105,000 ac-ft/yr. The frequency of the critical year has not yet been determined. The use of a guaranteed quantity of high-quality reclaimed water is considered a potential source for this required future water supply. The limiting factor, however, is the minimum reclaimed water that the SCVWD is able to accept both in dry and wet years. In dry years, there may not be enough surface or import water for blending with reclaimed water before recharge. In wet years, there may be too much surface water to be disposed of without either being wasted as runoff to the Bay or causing potential flood problems along flood control channels.

Water Quality

The quality of SCVWD water is very good. Table 1-1 presents a comparison of the Environmental Protection Agency (EPA) Drinking Water Standards and some limited water quality data for both groundwater and surface waters. The water quality in wells located throughout the valley varies considerably.

Table 1-1
Water Quality

	EPA Drinking Water Standard	SCVWD Groundwater[a]	South Bay Aqueduct[b]
TDS (mg/l)	500	350	304
Chloride (mg/l)	250	37	98
Sulfate (mg/l)	250	67	37
Nitrate (N)(mg/l)	10	3	0.55
Arsenic (µg/l)	50	<10	<0.005
Cadmium (µg/l)	10	1-2	<0.001
Chromium (µg/l)	50	<1-5	<0.01
Lead (µg/l)	15	<10-30	<0.005
Silver (µg/l)	50	<5	<0.001
TOC (mg/l)	--	0.2-1.5	<4.4

[a] Limited Testing Done in 1984 and 1985
[b] Average for 1987-1991

Notes:
N/A = Not Available mg = milligrams per liter µg/l = micrograms per liter

SCVWD Facilities

The SCVWD operates a variety of water storage, conveyance, treatment, and recharge facilities. This report focuses only on the recharge facilities.

Groundwater recharge to the groundwater subbasins occurs naturally as well as artificially through recharge facilities operated by the SCVWD. Surface runoff from the winter months is stored in a number of local reservoirs. This water is then recharged to the groundwater basin by a system of onstream and offstream recharge ponds, and by releases to several major surface streams. When needed, recharge of local runoff is augmented by recharge of imported water.

To enhance in-stream recharge, temporary gravel dams are erected in late spring to early summer. These dams are removed before winter for passage of flood waters.

The SCVWD currently operates eight recharge systems. Six of the systems are located in the North County and two are located in the South County near Morgan Hill and Gilroy. In this study, only the North County recharge systems are considered. The South County recharge systems are too remote from the San Jose area to be relevant in this study. The locations of some of the recharge ponds in the North County are shown on Figure 1-1.

All of the groundwater recharge facilities are located in the forebay area of the Santa Clara Valley Subbasin where the regional aquitard is not present. Most of the pumping occurs in the deeper aquifers. All water that recharges into the lower aquifers, whether from the percolation ponds or streambeds, will replenish the groundwater resource depleted by pumping. Any incidental recharge from the streambed downstream of the

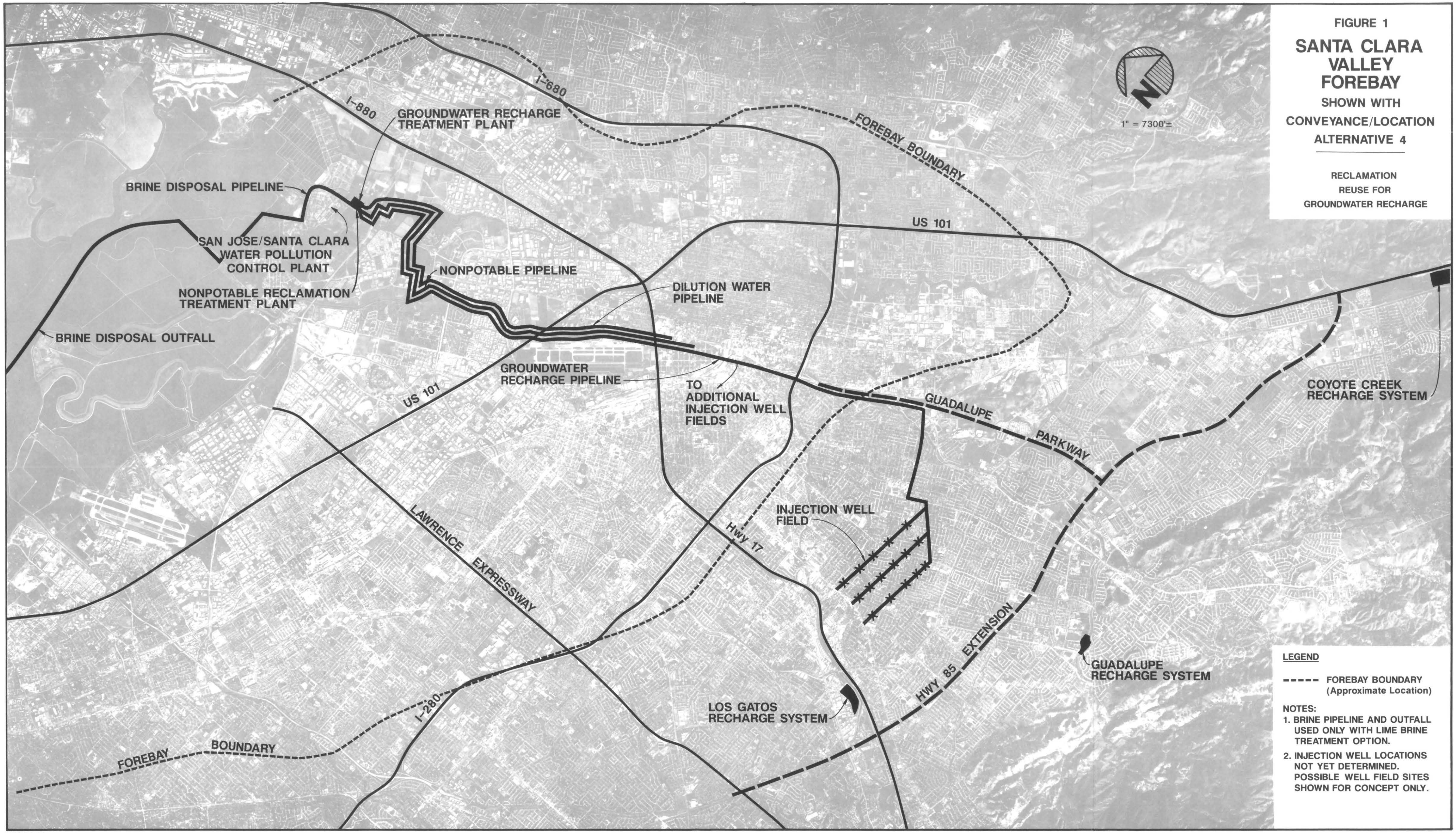
I-680
I-880
GROUNDWATER RECHARGE TREATMENT PLANT
FOREBAY BOUNDARY
BRINE DISPOSAL PIPELINE
SAN JOSE/SANTA CLARA WATER POLLUTION CONTROL PLANT
NONPOTABLE PIPELINE
US 101
DILUTION WATER PIPELINE
NONPOTABLE RECLAMATION TREATMENT PLANT
BRINE DISPOSAL OUTFALL
GROUNDWATER RECHARGE PIPELINE
TO ADDITIONAL INJECTION WELL FIELDS
US 101
GUADALUPE PARKWAY
COYOTE CREEK RECHARGE SYSTEM
INJECTION WELL FIELD
LAWRENCE EXPRESSWAY
Hwy 17
HWY 85 EXTENSION
GUADALUPE RECHARGE SYSTEM
LOS GATOS RECHARGE SYSTEM
I-280
FOREBAY BOUNDARY
1" = 7300'±
N

FIGURE 1

SANTA CLARA VALLEY FOREBAY

SHOWN WITH CONVEYANCE/LOCATION ALTERNATIVE 4

RECLAMATION REUSE FOR GROUNDWATER RECHARGE

LEGEND

- - - - FOREBAY BOUNDARY (Approximate Location)

NOTES:
1. BRINE PIPELINE AND OUTFALL USED ONLY WITH LIME BRINE TREATMENT OPTION.
2. INJECTION WELL LOCATIONS NOT YET DETERMINED. POSSIBLE WELL FIELD SITES SHOWN FOR CONCEPT ONLY.

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forebay will not recharge the lower aquifers and, consequently, will not contribute to the groundwater supply of the area.

The recharge facilities are discussed further in Chapter 3, Aquifer Storage.

SJ/SC WPCP Facilities

The SJ/SC WPCP was first constructed in 1956 as a primary treatment facility. Secondary treatment capabilities were added in the early 1960s, with tertiary facilities (nitrification and filtration) brought online in the late 1970s. The plant is one of the largest wastewater treatment facilities in the state and the largest advanced wastewater treatment plant in the state. The plant treats flows from the Cities of San Jose, Santa Clara, Milpitas, Cupertino, Campbell, Saratoga, Los Gatos, Monte Sereno, and several county sanitation districts.

The SJ/SC WPCP currently discharges an average annual flow of 120 mgd (drought-related restrictions have reduced flows). This compares to the design flow capacities of 160 mgd average annual and 167 mgd peak week. The facilities and the excellent capabilities of the plant staff have resulted in a high, reliable, and consistent level of treatment. These accomplishments are supported by the following facts as documented by detailed plant records for the years 1982 through 1992:

- The annual average biochemical oxygen demand (a measure of organic contamination) concentration was 4.1 mg/l, which represents a 98 percent removal. In addition, there were no violations of either the daily maximum or the 30-day average effluent limitations. The 1991 average was 3.3 mg/l.

- The annual average suspended solids concentration was 1.6 mg/l, which represents 99.3 percent removal. In addition, there were no violations of either the daily maximum or 30-day average effluent limitation. The 1991 average was 1.6 mg/l.

- The annual average for turbidity was 1.1 nephelometric turbidity unit (NTU) as compared to the current drinking water standards of 1.0 NTU (will change to 0.5 NTU in June 1993). In addition, there were no violations of the daily maximum limitation.

As evidence of the excellent operation and maintenance at the WPCP, the EPA selected the SJ/SC WPCP as the 1989 Large Plant of the Year in Region IX, and in national competition the WPCP was given the second highest rating when compared to plants in all the EPA regions. The WPCP has also won other EPA operations and maintenance awards in 1986, 1987, and 1988. In addition the plant won the 1989 American Consulting Engineers Council Honor Award for engineering excellence.

The SJ/SC WPCP is located at the southern tip of the South Bay between Alviso and Milpitas (Figure 1-1). The plant was designed and constructed with a high level of reliability and redundancy as required for discharge into the environmentally sensitive South Bay. Figure 1-2 is a schematic depicting the major plant processes.

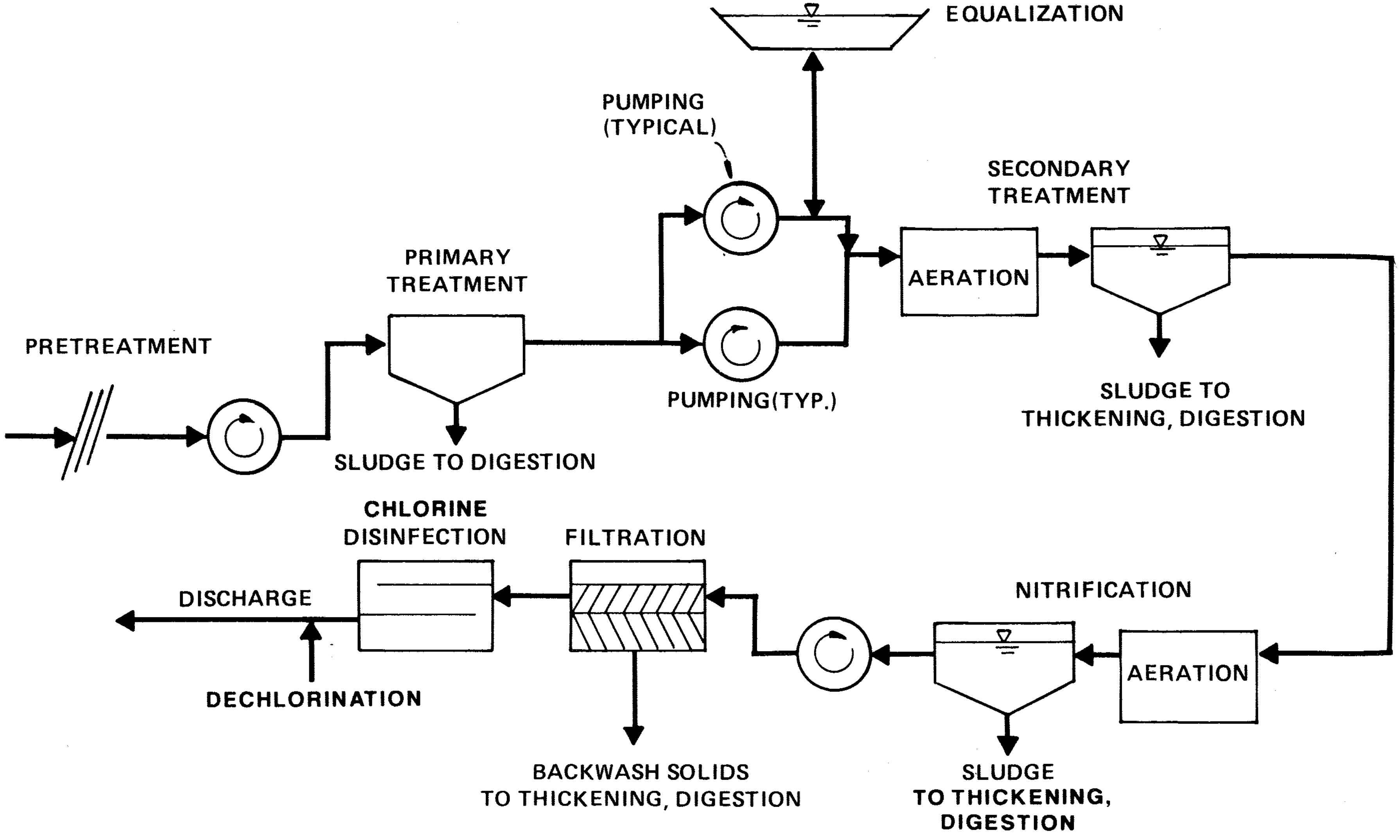

FIGURE 1-2
PROCESS SCHEMATIC
San Jose/Santa Clara WPCP

CH2M HILL

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Chapter 2
Groundwater Recharge Opportunities

Section 2

Groundwater Recharge Opportunities

Previous Reuse Projects

Three forms of potable wastewater reuse occur throughout the world (unintentional reuse, and direct and indirect potable reuse). Unintentional reuse occurs in areas where a waste discharge becomes part of a water source, either a groundwater aquifer or a surface water. An example of this in California is the discharge of treated effluent from the Sacramento Metropolitan Wastewater Plant into the Sacramento River. This effluent becomes a small part of the flow in the Sacramento River, which contributes to the source at Clifton Court Forebay for the California Aqueduct and the Contra Costa Canal. On a national scale, it has generally been concluded that Ohio River water has been used five times before it reaches the confluence of the Mississippi River. That is, the water has been extracted for domestic and industrial use, and discharged through to wastewater treatment plants to the river approximately five times.

The Santa Ana River

The majority of the flow in the Santa Ana River downstream from Prado Dam is dominated by treated wastewater flow returned to the river channel. With two exceptions, the secondary effluent is filtered and disinfected. The water recharges the local aquifer in the vicinity of the river and adds to the groundwater used by domestic utilities in that area. No formal modeling or health effects work has been done on the entire river recharge system, but limited data from downstream wells sampled as a part of the *LACSD Health Effects Study* indicate that wells in Anaheim near the river have TOC levels from 0.2 to 0.4 mg/l. Upstream discharger TOC is unknown, but may be assumed to be similar to other filtered secondary effluent. To date, no work has assessed the impact of the percent of the upstream discharge that reaches domestic wells.

Both direct and indirect potable reuse are also possible, although there are no known examples of direct reuse in operation at this time. Direct reuse occurs when the treated wastewater is placed directly into the distribution system of a water utility without the intermediate step of dilution either in the groundwater or a surface water source. Indirect reuse has been practiced in California since at least 1962 and possibly on an unintentional basis before that time.

The State of California has regulations for the use of reclaimed water for groundwater recharge that have been in place since 1978 (Ref. 2-1) and is currently in the process of rewriting those regulations (Ref. 2-2) to reflect the changes that have taken place over the last 13 years. The original wastewater reclamation regulations, adopted in 1918 and revised in 1933 and again in 1967, did not contain a provision for groundwater recharge. In each case, these projects were started for different reasons. They may have been started as a part of a wastewater disposal option or some other issue not related to potable recharge.

Specific regulations to govern the use of reclaimed water to augment a surface water source, such as is the case in Virginia at the Upper Occoquan Sewage Authority, do not exist in California. Any proposals for this use would be handled on a case-by-case basis by the Department of Health Services (DOHS) and the appropriate RWQCB utilizing the existing laws and regulations. The following is a brief chronology of groundwater recharge projects and activities that have taken place both in California and in other states in the last 30 years including operations, regulations, and studies relating to indirect reuse. Specific details about some of the operating projects are included in this chapter.

- 1962–Los Angeles County Sanitation Districts start recharge operations using basins and a combination of local and imported surface water and secondary effluent at Whittier Narrows in the San Gabriel River.
- 1967–Reclamation criteria published without language addressing groundwater recharge.
- 1975–"State-of-the-Art" Review of Health Aspects of Wastewater Reclamation for Groundwater Recharge, November 1975, developed and published by DOHS, DWR, and SWRCB.
- 1976–Orange County Water District (OCWD) begins direct injection of a mix of reclaimed wastewater and deep well water into the potable groundwater aquifer.
- 1977–Pomona Virus Study Final Report published by the Los Angeles County Sanitation Districts and the SWRCB demonstrating equivalent virus removal using direct filtration versus complete conventional water treatment. This allowed additional work to proceed on a cost-effective basis by eliminating the need for sedimentation facilities at all wastewater filtration operations.
- 1978–Upper Occoquan Sewage Authority (UOSA), Virginia, begins discharging tertiary effluent into surface water for subsequent treatment and use in the potable supply.

- 1978–Wastewater Reclamation Criteria published by DOHS including current groundwater recharge regulations.

- 1979–Water Factory 21 Virus Study completed demonstrating virus removal using facilities at Orange County Water District.

- 1984–Health Effects Study published by the County Sanitation Districts of Los Angeles on the Whittier Narrows/Montebello Forebay recharge project.

- 1985–Denver Water Board Potable Water Reuse Demonstration Project startup with a 1-mgd demonstration plant. Work includes health effects testing.

- 1986–Tampa Water Resource Recovery Pilot project starts with a 50-gpm pilot plant. Work includes health effects testing.

- 1987–Report of the Science Advisory Panel on Groundwater Recharge with Reclaimed Wastewater published by DOHS, DWR, and SWRCB.

- 1991–Tampa and Denver pilot and demonstration projects complete testing, and DOHS develops draft revised regulations for groundwater recharge.

County Sanitation Districts of Los Angeles, California

The Sanitation Districts of Los Angeles County (SDLAC) have been using reclaimed wastewater for a portion of their groundwater recharge since 1962. The original project was viewed more as a disposal option, rather than as an intentional groundwater recharge operation. Recharge had been operational in this area before 1962 using local surface water runoff.

The collection area for the SDLAC plants is characterized as industrial/commercial/domestic. From 1962 to 1977, the reclaimed wastewater used for replenishment was disinfected secondary effluent. Dual-media filtration was then added to improve virus inactivation during disinfection. This addition to the treatment followed completion of the Pomona Virus Study that demonstrated equivalent virus removal using direct filtration (without sedimentation) versus complete conventional water treatment including sedimentation facilities. From 1962 to 1983, the amount of reclaimed water in the total recharge amount averaged 22,000 ac-ft/yr and 12.7 percent of the total recharge. The wastewater varied from 1,000 ac-ft in the first year to 32,000 ac-ft in 1982, and from 0.4 to 23 percent of the recharge water. The remaining amount of the water is made up of local runoff into the San Gabriel River basin and imported water from the Colorado River and the State Water Project. Until 1983, the total allowable amount of reclaimed wastewater in the recharge program was 32,000 ac-ft. After conducting the health effects study required by DOHS, described later under "Health Effects Studies," the Los Angeles RWQCB gave the SDLAC authorization for an increase to an average annual maximum of 50,000 ac-ft.

Recharge into the Central Basin groundwater is accomplished in the Montebello Forebay located in the northerly portion of the Central Basin immediately below Whittier Narrows. This area is traversed by the San Gabriel River and the Rio Hondo (tributary to the Los Angeles River); both carry runoff from the San Gabriel Valley through the Whittier Narrows into the Central Basin. The Rio Hondo spreading facility is the largest replenishment location, having a total of 455 wetted acres. The San Gabriel River spreading basins have 101 wetted acres with an additional 133 acres of river bottom that can be used if needed. Both of the spreading areas are subdivided into individual basins ranging from 4 to 20 acres. Under normal operating conditions, batteries of basins are rotated through a 21-day cycle consisting of (1) a 7-day flooding period during which the basins are filled to maintain a constant 4-foot depth, (2) a 7-day draining period during which the flow to the basins is terminated and the basins are allowed to drain, and (3) a 7-day drying period. This wetting/drying operation allows the upper strata in the basins to remain aerobic and also serves to prevent problems with mosquitos and other vectors. The need to practice the wetting/drying operation in the SCVWD percolation basins needs to be resolved in future studies.

The capacity of the spreading grounds during normal operation is about 300 cubic feet per second (cfs); during storm periods when all basins are in use the capacity increases to 950 cfs. During "normal" operations the 50,000 ac-ft/yr of reclaimed water would comprise approximately 23 percent of the recharge, but because of increased recharge during storm periods the actual percentage is somewhat less. The remainder of the recharge is dilution water made of local runoff plus imported water.

To evaluate the effects on health from using treated wastewater for groundwater recharge in the potable supply, a study was initiated by SDLAC in November 1978. The study was designed following the recommendations developed in the 1975 State-of-the-Art Review of Health Aspects of Wastewater Reclamation for Groundwater Recharge that was developed by the State of California using an "Expert Panel." The SDLAC study, Health Effects Study Final Report (Ref. 2-3), was completed in March 1984 at an approximate cost of $1.6 million, and included five major tasks:

- Characterization of the quality of the groundwater, reclaimed water, and other replenishment sources in terms of their microbiological and inorganic chemical content.

- Toxicological and chemical studies of groundwater, reclaimed water, and other replenishment sources to isolate and identify organic constituents of significance to health.

- Percolation studies to evaluate the efficacy of soil for attenuating inorganic and organic chemicals in reclaimed water.

- Hydrogeological studies to determine the movement of reclaimed water through groundwater and the relative contribution of reclaimed water to municipal water supplies.

- Epidemiological studies of populations ingesting reclaimed water to determine whether their health characteristics differed significantly from a demographically similar control population.

The study concluded that..."Extensive evaluation of the Whittier Narrows groundwater replenishment project did not demonstrate any measurable adverse impacts on the area's groundwater or the health of the population ingesting this water, long-term health effects need to be studied further." (Ref. 2-4).

The recharge project is continuing, and additional routine monitoring is being conducted to ensure the safety of the replenishment operation. Table 2-1 summarizes the quality of the reclaimed water, the imported water, and both the chlorinated and unchlorinated well water (from the Health Effects Study).

Data developed by the SWRCB in 1990 (Ref. 2-5) indicate that in 1987 the SDLAC recharged 35,939 ac-ft into the Rio Hondo and San Gabriel Spreading Grounds from the Pomona, San Jose Creek, and Whittier Narrows Water Reclamation Plants. The plants' effluent TOCs ranged from 5 to 18 mg/l, with an average of about 14 mg/l. The impact of the recharge operations can be demonstrated on approximately 300 wells operated by 32 water purveyors in the Central and West Basin Metropolitan Water Districts. The population in the Central Basin area closest to the recharge operations was estimated at 486,000 (Ref. 2-6) people during the Health Effects Study. The amount of reclaimed water that reaches the wells in the vicinity ranges from less than 1 to 23 percent, with the average being approximately 11 percent. The impact of the recharge is far less in the West Basin area than in the Central Basin because of the distance and time of travel.

The groundwater nondegradation standards were not in effect when this project began operations. There is no evidence that the groundwater quality has been degraded by the recharge of reclaimed water. Except for increasing sulfate concentrations, the groundwater quality has remained fairly constant with time. The increasing sulfate levels result from high concentrations in the Colorado River Water.

Table 2-1

AVERAGED WATER QUALITY DATA FOR MONTEBELLO FOREBAY SAMPLES

Parameter	Drinking Water Standards[a]		Reclaimed Water[b]			Imported Water			Unchlorinated Well Water			Chlorinated Well Water	
	Primary	Secondary	$Cl_2/DeCl_2$ 3°	Cl_2 2°	$UnCl_2$ 2°	Storm Water	Colorado River	State Project	High[c]	Low[d]	Control[e]	High[c]	Low[d]
Turbidity, NTU	0.5-5	5	0.8	2.3	1.9	79.2	1.9	2.4	1.7	< 0.2	< 0.5	0.5	0.3
Color, CU	-	15	22.5	28.3	36.7	698.3	< 5	21.7	< 7	< 5	< 5	< 5	< 5
pH	-	-	7.23	7.73	7.52	7.68	8.00	8.07	7.65	7.81	7.90	7.51	7.36
Dissolved Solids, mg/L	-	500-1500	568	588	560	179	664	339	464	478	277	492	713
Total Alkalinity, mg/L $CaCO_3$	-	-	220	276	276	59	127	72	162	201	161	189	258
Chloride, mg/L Cl	-	250-600	133	129	111	19	96	61	62	45	18	105	67
Sulfate, mg/L SO_4	-	250-600	113	102	102	46	308	34	125	123	48	179	200
Nitrate, mg/L N	10.0	-	0.34	0.13	0.19	1.78	0.16	0.60	2.31	1.51	0.93	0.57	3.68
Nitrite, mg/L N	-	-	0.40	0.52	0.50	0.14	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ammonia, mg/L N	-	-	13.7	20.7	20.5	1.3	< 0.1	< 0.1	< 0.1	< 0.2	< 0.2	< 0.1	< 0.1
Phosphate, mg/L PO_4	-	-	10.6	6.9	7.2	2.4	0.8	0.3	0.6	0.2	< 0.1	< 0.1	0.7
Fluoride, mg/L F	1.4-2.4	-	0.65	0.66	0.60	0.23	0.37	< 0.13	0.43	0.40	0.36	0.51	0.23
Cyanide, mg/L CN	-	-	< 0.01	< 0.01	0.02	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02
Total Hardness, mg/L $CaCO_3$	-	-	194	212	211	100	334	93	242	309	255	279	445
Arsenic, mg/L As	0.05	-	0.003	0.004	0.003	0.010	0.003	0.002	0.004	0.003	0.002	0.004	0.002
Barium, mg/L Ba	1.0	-	0.22	0.20	0.23	0.26	0.46	0.16	0.29	0.29	0.29	0.33	0.54
Cadmium, mg/L Cd	0.01	-	< 0.002	0.004	0.004	0.002	0.002	< 0.001	<0.002	0.002	< 0.001	0.002	0.003
Chromium, mg/L Cr	0.05	-	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	< 0.01
Copper, mg/L Cu	-	1.0	0.008	0.016	0.015	0.046	< 0.006	< 0.010	<0.007	< 0.005	< 0.005	< 0.006	0.014
Iron, mg/L Fe	-	0.3	< 0.06	0.07	0.09	0.13	0.18	0.22	0.40	0.02	< 0.01	0.07	< 0.02
Lead, mg/L Pb	0.05	-	< 0.02	0.02	0.03	0.09	< 0.01	< 0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02
Manganese, mg/L Mn	-	0.05	< 0.01	0.02	0.02	0.18	0.01	0.01	<0.05	< 0.05	< 0.01	0.02	< 0.01
Mercury, mg/L Hg	0.002	-	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	<0.0001	< 0.0001	< 0.0001	0.0004	< 0.0001
Nickel, mg/L Ni	-	-	0.05	0.07	0.07	0.02	< 0.01	0.01	<0.01	< 0.09	< 0.01	0.01	0.02
Selenium, mg/L Se	0.01	-	< 0.003	0.003	0.003	< 0.003	< 0.003	< 0.002	<0.002	0.002	< 0.001	0.003	0.004
Silver, mg/L Ag	0.05	-	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	<0.001	< 0.001	< 0.002	0.002	0.002
Sodium, mg/L Na	-	-	105	126	116	19	91	45	59	40	19	109	56
Zinc, mg/L Zn	-	5.0	0.03	0.05	0.05	0.10	< 0.01	0.05	0.02	< 0.01	0.09	0.14	0.03
TOC, mg/L C	-	-	11.2	14.1	12.6	16.4	3.2	4.3	0.8	0.6	0.3	2.2	0.7
Bromide, mg/L Br	-	-	< 0.30	0.32	0.31	0.14	0.11	0.22	0.21	0.18	0.05	0.38	0.18
Total Coliform, MPN/100 mL	-	-	8	< 8	$>5.0 \times 10^5$	$>6.2 \times 10^4$	< 2	14	< 2	< 2	< 2	< 2	< 2
Fecal Coliform, MPN/100 mL	-	-	< 2	< 2	$>2.8 \times 10^4$	$>8.7 \times 10^3$	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Fecal Strep, MPN/100 mL	-	-	< 2	< 2	$>8.8 \times 10^2$	$>1.1 \times 10^5$	< 2	< 3	< 2	< 2	< 2	< 2	< 2
Total Plate Count/mL	-	-	194	83	$>2.9 \times 10^4$	7.7×10^4	< 1	49	<17	< 1	4	< 1	<10

a/ California Domestic Water Quality and Monitoring Regulations, Articles 4 and 8, Title 22, California Administrative Code, 1977.
b/ $Cl_2/De\ Cl_2$ 3° = chlorinated/dechlorinated tertiary effluent; Cl_2 2° = batch chlorinated secondary effluent; $UnCl_2$ 2° = unchlorinated secondary effluent.
c/ Wells containing > 5 percent reclaimed water.
d/ Wells containing ≤ 5 percent reclaimed water.
e/ Wells containing no reclaimed water.

This project relates most directly with the proposed project in the Santa Clara Valley because of the groundwater recharge basins and the large number of domestic water supply wells in the vicinity of the basins. The proposed project, because of new regulations, will provide a higher degree of treatment than is currently being provided by SDLAC.

Orange County Water District, California

Since 1976, OCWD has operated an advanced wastewater treatment plant to provide 15 mgd of reclaimed water for groundwater recharge via direct injection. They reclaim unchlorinated secondary effluent from the Orange County Sanitation District plant in Fountain Valley, which has a commercial/domestic collection system, and provide advanced treatment, including lime clarification, filtration, activated carbon adsorption, partial reverse osmosis (RO), and disinfection.

The reclaimed water is blended with deep well water and injected using a series of wells to provide a seawater intrusion barrier to protect the domestic wells in Orange County. An estimated 5 percent of the reclaimed water is added to the domestic supply, with the remainder being used to maintain the salinity barrier. Since the start of the project, the injected water has averaged 55 percent treated wastewater, with the remainder coming from deep wells. The current blend is one-third wastewater treated with RO, one-third wastewater treated with granular activated carbon (GAC), and one-third deep well water.

The OCWD plant, named Water Factory 21, has demonstrated its reliability in meeting both EPA drinking water standards and other health criteria. In addition, a virus monitoring study (Ref. 2-7) was conducted from November 1975 through February 1979. The results indicate that the effluent from the plant was free of virus in all but two samples (out of a total of 123 samples of the chlorinated effluent), and that the treatment provided is able to provide water that is microbiologically safe. The two positive samples were during periods of higher-than-normal effluent turbidity and may have been because of cross contamination during the sampling procedure.

The quality of the injected water has varied since the beginning of the project because of the changes in treatment. In 1980 the quality was reported as shown in Table 2-2 (taken from "Reliability of Water Factory 21" [Ref. 2-8]). Additional work was also done by OCWD and reported in "Quality Criteria for Water Reuse" (Ref. 2-9) to determine the water quality and the removal efficiency for various compounds and elements. These data are shown in Tables 2-3, 2-4, and 2-5 and indicate that, with the exception of nitrate, all contaminants of concern were removed to a high degree by the treatment processes. Nitrate increased a slight amount (influent 2.8 milligrams per liter (mg/l) as N; RO effluent 3.3 mg/l as N) because of the conversion of ammonia to

Table 2-2

Comparison of State Specified Maximum Contaminant Levels With Water Factory 21 Injection Water Levels*

Contaminant	State MCL	Influent Geom. Mean	Injection Water Geom. Mean**	Number of Times MCL Exceeded
Ammonia	4	1.4	0.37	0/238
Sodium	110	166	84	5/51
Total Hardness	220	301	86	0/50
Sulfate	125	200	74	1/50
Chloride	120	190	90	4/50
Fluoride	0.8	1.3	0.55	2/50
Boron	0.5	0.7	0.38	0/51
MBAS	0.5	0.24	<0.04	0/48
Chromium	0.05	0.051	0.004	2/47
Cadmium	0.01	0.037	0.002	1/47
Selenium	0.01	0.0047	0.004	0/47
Copper	1.0	0.087	0.013	0/47
Lead	0.05	0.0078	0.0013	0/47
Mercury	0.005	0.0007	0.0006	0/47
Arsenic	0.05	0.006	0.003	0/47
Iron	0.3	0.090	0.02	1/46
Manganese	0.05	0.036	0.003	0/47
Barium	1.0	0.0350	0.004	0/47
Silver	0.05	0.0023	0.001	0/47
Cyanide	0.2	0.020	0.003	0/50
Total Nitrogen	10.0	4.93	<6.5	0/238
Phenol	0.001	0.006	<0.0014	20/50
COD	30	46.2	13.1	0/238
Coliforms	<2.2/100 ml	$8.1x10^5$	<1.0	0/187
Elec. Cond.	900 µmho	1380	598	0/365
Turbidity	1.0 TU	9.85	0.42 TU	0/365

*All units mg/l except where otherwise specified

**All means on blended injection water except COD (Q-8) and Turbidity (Q-6)

Table 2-3

Comparison Between the Maximum Contaminants Levels (MCL's) Recommended in the National Interim Primary Drinking Water (NIPDW) Regulations and Levels Found in Influent Water at Factory 21[a]

		Influent Water			
		First Period Studied		Second Period Studied	
Contaminant	MCL	Geometric Mean	98% of Time Less Than:	Geometric Mean	98% of Time Less Than:
mg/liter:					
Arsenic	0.05	0.005	0.005[b]	0.005	0.005[b]
Barium	1.0	0.08	0.14	0.03	0.06
Cadmium	0.01	0.026[c]	0.07	0.033	0.15
Chromium	0.05	0.14	0.31	0.048	0.11
Lead	0.05	0.02	0.051	0.007	0.017
Mercury	0.002	0.0016	0.025	0.001	NK[g]
Nitrate (as N)	10	0.23	1.2	2.8	49
Selenium	0.01	0.0025	0.0025[b]	0.0025	NK[g]
Silver	0.05	0.003	0.007	0.001	0.006
Fluoride	1.4[d]	1.4	2.0	1.3	1.9
µg/liter:					
Endrin	0.2	0.01	0.01	0.01	0.01
Lindane	4	0.2	0.9	0.14	0.22
Toxaphene	5	0.01	0.01	0.01	0.01
2,4-D	100	0.01	0.01	0.01	0.01
2,4,5-TP	10	0.01	0.01	0.01	0.01
Methoxychlor	100	0.1	0.1	0.01	0.01
MPN[e]/100 ml:					
Coliforms	1	89	38,000	1.6	195
TU[f]:					
Turbidity	1	42	79	7	54

[a] From McCarty *et al.*, 1980.

[b] Based on less than 1 in 20 samples analyzed.

[c] Underlined values represent those exceeding MCL's.

[d] Temperature = 26.3°C.

[e] MPN = Most probable number.

[f] TU = Turbidity units.

[g] Not known.

Table 2-4

Selected Contaminant Concentrations and Effectiveness of Treatment at Water Factory 21 in Removing Them[a]

Contaminant or Other Factor Measured	Concentration as Noted: AWT Plant[b] Influent	Concentration as Noted: AWT Plant[b] Effluent	Concentration as Noted: RO[c] Effluent	Percent Removal: AWT[b]	Percent Removal: AWT[b] and RO	Dominant Removal Processes[d]
Chemical oxygen demand (COD), mg/liter	47	12	1.3	74	97	ppt, GAC, RO
Total organic carbon (TOC), mg/liter	12	6	2.6	50	78	ppt, GAC, RO
Total dissolved solids (TDS), mg/liter	900	850	77	5	91	RO
Electroconductivity (EC), µS/cm	1,500	1,320	156	12	90	RO
Nitrogen, mg N/liter:						
Organic	2.0	1.1		45		ppt
Ammonia	4.0	0.8		80		strip, Cl_2
Nitrate	2.8	7.7	3.3	-175	-18	
Boron, mg/liter	0.74	0.53		28		
Fluoride, mg/liter	1.3	0.81		38		
Coliforms, MPN[e]/100 ml						
Total	1.6×10^6	0.05		100		ppt, Cl_2
Fecal	0.55×10^6	<1		100		ppt, Cl_2
Phenol, µg/liter	14.9					
Cyanide, µg/liter	25	6.9		72		
Color, units	37	0.8		98		
Methylene blue active substance (MBAS), mg/liter	0.25	0.08		68		

[a] From McCarty et al., 1980.

[b] AWT refers to all advanced wastewater treatment processes except reverse osmosis (RO).

[c] RO = Reverse osmosis.

[d] ppt = Chemical precipitation with lime.
GAC = Granular activated carbon.
Strip = Air stripping.

[e] MPN = Most probable number.

Table 2-5

Concentrations of Organic Contaminants and Effectiveness of Treatment at Water Factory 21 in Their Removal[a]

	Concentration (μg/liter)			Percent Removal		
Contaminant	AWT[b] Plant Influent	AWT[b] Plant Effluent	RO Effluent	AWT[b]	AWT[b] & RO	Dominant Removal Processess[c]
Aromatic hydrocarbons						
Ethylbenzene	0.043	0.014	0.019	67	56	NR[d]
m-Xylene	0.035	0.020	0.024	43	31	NR
p-Xylene	0.015	0.012	0.014	20	7	NR
Naphthalene	0.033	0.010	0.028	70	15	NR
1-Methylnaphthalene	0.008	0.009	0.00	-12	88	NR
2-Methylnaphthalene	0.010	0.02	0.008		20	NR
Styrene	0.048	0.003		94		NR
Synthetic chlorinated compounds						
Carbon tetrachloride	0.033	0.16	0.008	-380	76	Strip
1,1,1-Trichloroethane	3.25	0.20	0.083	94	97	Strip
Trichloroethylene	0.74	0.10	0.1	86	86	Strip
Tetrachloroethylene	1.67	0.83	0.20	50	88	Strip
Chlorobenzene	0.14	0.049	0.034	65	76	Strip, GAC
1,2-Dichlorobenzene	0.64	0.02	0.001	97	99.9	Strip, GAC
1,3-Dichlorobenzene	0.16	0.02	0.004	88	97.5	Strip, GAC
1,4-Dichlorobenzene	1.85	0.012	0.015	99	99	Strip, GAC
1,2,4-Trichlorbenzene	0.11	0.02	0.02	82	82	Strip, GAC
Lindane	0.14	0.05	0.05	64	64	ppt, GAC
PCB (Aroclor 1242)	0.47	0.3	0.3	36	36	ppt, GAC
Chlorination products						
Chloroform	3.1	8.6	0.97	-177	69	Strip, GAC
Dichlorobromomethane	0.53	2.7	0.24	-410	55	Strip, GAC
Chlorodibromomethane	0.69	1.3	0.13	-88	81	Strip, GAC
Bromoform	0.40	0.38	0.007	5	98	Strip, GAC
Phthalate esters						
Dimethylphthalate	4.8	0.47	1.0	90	79	ppt, GAC
Diethylphthalate	0.097	0.3	0.3			
Di-*n*-butylphthalate	0.79	0.33	1.1	58	-39	ppt, GAC
Diisobutylphthalate	4.7	0.27	0.23	94	95	ppt, GAC
Bis-(2-ethylhexyl) phthalate	11.0	3.1	2.9	72	74	ppt

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[a] From McCarty *et al.*, 1980.

[b] AWT refers to all advanced wastewater treatment processes except RO.

[c] Strip = chemical precipitation with time

GAC = granular activated carbon

ppt = chemical precipitation with lime

[d] NR = not reported.

nitrate. Total organic carbon was (TOC) reduced from 12 mg/l to 2.6 mg/l through the plant.

The OCWD has received the authorization to change the provisions in their discharge permit to allow injection of 100 percent reclaimed water rather than the blended supply currently in use. This will require them to increase treatment capacity to meet the increased demand for reclaimed water, and the percentage of reclaimed water in the groundwater will increase to an estimated 6 to 7 percent over time because of the elimination of the deep well water currently used for blending.

This project was originally started to provide a seawater intrusion barrier and it was assumed that none of the reclaimed water would enter the domestic supply. Over time, advances in groundwater modeling have demonstrated that the recharged water does enter the domestic supply to a small degree. The main lesson to be learned from this project relates to the reliability of the treatment provided by OCWD, and the applicability of RO in a large-scale treatment plant.

Upper Occoquan Sewage Authority, Virginia

The UOSA, located in northern Virginia, operates a 15-mgd advanced wastewater treatment facility that has a commercial/domestic collection system. The plant's effluent discharges directly to Occoquan Reservoir. Water is taken from the reservoir, treated, and distributed to approximately one million of the water consumers in Fairfax County. The reservoir is the principal raw water supply for northern Virginia. The advanced waste treatment plant has operated since 1978, and contributes a significant percent of the inflow to the reservoir. This project was originally started to eliminate numerous small substandard wastewater plants that were in this watershed and that discharged effluent to tributaries of the reservoir.

The UOSA plant uses conventional secondary treatment followed by lime clarification, filtration, activated carbon adsorption, ammonia removal, and chlorination. Buffering storage is also used before effluent is discharged to the reservoir and to ensure that substandard effluent can be retreated before it is discharged. TOC levels in the influent average about 100 mg/l and in the effluent about 3 mg/l.

The percentage of recycled water in the domestic supply varies with the hydrologic conditions. The amount of inflow to the reservoir has been as high as 80 percent recycled water during September 1977, and averaged 90 percent during the drought of 1980-81. The percent of inflow to the reservoir does not equal the percent of recycled water in the domestic supply because of carry-over storage. On the average, the amount of wastewater in the domestic supply is probably less than 20 percent, but data are not available to accurately determine the blend on a historical basis.

This project demonstrates the reliability of the treatment process and the subsequent water quality impacts on the domestic system. To date there have not been any adverse water quality impacts on the domestic supply. At this time, health effect studies have not been conducted.

Clayton County Water Authority, Georgia

The Clayton County Water Authority (CCWA) is located just south of Atlanta, Georgia, and provides domestic water and sewerage service to the 42,000 residents of the county. In 1979 they developed a land treatment system for the domestic wastewater that uses secondary wastewater to irrigate forests. The average water use is 20 mgd and results in an average waste discharge of 14 mgd. All the effluent is disposed of by spray irrigation of 3,700 acres of pine forest at an average application rate of 2.5 inches per day. The effluent percolates into the soil mantle and eventually adds to the natural flow of Pates Creek, a major tributary to Little Cotton Indian Creek raw water reservoir. This water is treated by CCWA and distributed to the service population.

This project was originally conceived as a waste disposal option rather than as a potable water supply augmentation project.

Data developed by CCWA indicate that the flow in Pates Creek has increased an average of 12 mgd (ranging from 6 to 19 mgd). The staff also estimate that 45 percent of the applied effluent can be counted as increased streamflow on an annual basis. The raw water reservoir has two other creek systems that add to the source, and while Pates Creek may be the major source, the reservoir is not dominated by the return flow from the land application area.

Groundwater levels in the area of the land application have also increased. The CCWA has established a groundwater monitoring network in the immediate area to determine changes in water quality. All wells are monitored monthly to assess the changes in water quality downgradient from the application area. After 3 years of operation, the only change identified was a slight increase in chloride in the groundwater from 3.1 to 4.6 mg/l.

Hueco Bolson Recharge Project, El Paso, Texas

El Paso Water Utilities has completed construction on the Hueco Bolson Recharge project in the northernmost well field in El Paso. Construction was completed and the project started up in 1985-86; it consists of the 10-mgd Fred Hervey Reclamation Plant and 10 injection wells. The plant's collection system is characterized as industrial/commercial/domestic. The plant currently operates at approximately 8 mgd and includes primary treatment followed by a two-stage PACT^{R} system, lime treatment, sand filtration, ozone disinfection, GAC adsorption, chlorination, and batch storage before injection. The PACT^R system is a two-stage biological/physical process combining biological treatment and the use of powdered activated carbon (PAC). The first stage is used for carbonaceous removal, nitrification, and organic removal. The second stage uses methanol for denitrification and organic removal. TOC levels in the plant influent average about 35 mg/l, and the effluent is about 2 mg/l.

A hydrogeologic study and summary paper (Ref. 2-10) prepared before the project began predicted that the residence time in the groundwater would be approximately 2 years; however, the actual travel time has been approximately 4 to 5 years since startup and operation. No estimate is available currently to determine the percentage of the wastewater in the domestic wells that are downstream of the injection zone.

This project was conceived as a groundwater augmentation project from the start. The increasing demand in the El Paso area could not be met by any other competing project, and still produce the same amount of water at the same cost.

Health Effects Studies

The question of human health effects and the relationship to water reclamation projects has been of interest since the first planned reclamation projects went on line in California in the early 1900s. Original concerns included contamination of drinking water by untreated waste and the potential for contamination of food crops by irrigation with untreated wastewater. These original concerns have been addressed and satisfied. Current regulations adequately protect the health of those individuals who consume food crops irrigated with reclaimed water (properly treated), and those individuals who come into contact with the effluent. The major questions that remain include using reclaimed water for potable purposes, either direct or indirect, and the long-term health effects of using reclaimed water. It is assumed that the microbiological questions have been largely answered by advances in disinfection practices and that the remaining questions involve long-term or chronic health effects from ingestion of reclaimed water. The majority of the work that has been done on planned reuse projects' health effects has occurred since the mid-1970s and has been driven by increasingly sophisticated reclamation proposals involving indirect ingestion. The following is a summary of some of the recent health effects work that has been done.

General Health Effects Studies

Before the initiation of the project-specific health effects studies listed below, several general studies were done to attempt to identify both the contaminants of concern and specific health impacts from using reclaimed water. These are listed in chronological order with a brief description of the nature of the work and the findings.

A "State-of-the-Art" Review of Health Aspects of Wastewater Reclamation for Groundwater Recharge (Ref. 2-11). This review was done using a consulting panel comprising 11 individuals representing academia, consulting engineering, the water utility industry, the EPA, and consumer groups. It was staffed by members of the three state agency sponsors who compiled a list of concerns regarding the use of reclaimed water in groundwater recharge operations and wrote a report. The report, issued in 1975, also included a list of needed research to advance the field of groundwater recharge and identified areas where more information was required before additional recharge projects could proceed. The general consensus of the review was that projects involving direct potable reuse without intermediate mixing in either the groundwater or another source are not appropriate; projects involving injection may be appropriate depending upon time of travel and blending within the aquifer; and projects that use surface spreading have the greatest potential for success depending upon the amount of water recharged, the dilution with other sources, the time of travel before extraction, and the quality of the effluent and the extracted water.

Contaminants Associated with Direct and Indirect Reuse of Municipal Wastewater (Ref. 2-12). This work was done under contract to the Health Effects Research Laboratory in Cincinnati, Ohio. The report, issued in 1978, is an attempt to compile the published quantitative data available concerning the health effects associated with direct and indirect reuse of treated municipal wastewater for potable purposes. The information includes data on the effectiveness of conventional water and wastewater treatment and disposal operations in reducing public health contaminant concentrations, as well as data on the transport of these contaminants through the environment back to humans.

Evaluations were done on the following:

- Wastewater treatment processes, including conventional secondary and advanced waste treatment processes
- Wastewater disposal techniques, including direct discharge to fresh surface waters and land application
- Water treatment processes including conventional treatment
- Advanced processes such as carbon adsorption, ion exchange, and RO

Cancer Incidence and Reuse of Drinking Water (Ref 2-13). In the United Kingdom, many lowland rivers are used both as a drinking water source and as a means of transporting domestic and industrial wastes to the sea. The contribution of rivers to the drinking water supply of London residents has been increasing gradually over the last 50 years. This study of 14 boroughs in the south London area examines cancer incidence using registry data for the period 1968-1974 to assess possible risks associated with water reuse. Socioeconomic characteristics of the boroughs were taken from the 1971 census, and positive associations were found between the average percentage of domestic sewage effluent in the water supplied to a borough and the incidence of stomach cancer and of urinary cancer in females. These associations were reduced when social factors and variations in borough size were taken into account. This study was published in the *American Journal of Epidemiology* in 1983.

In spite of the difficulties faced with the interpretation of the data common to aggregate studies of this type, the author concluded that this study provided some consistent epidemiologic evidence of a small potential health risk associated with the consumption of drinking water that contains treated or untreated wastewater as a component. The study also concludes that more work should be done to attempt to define the nature of a possible association between cancer and water reuse.

It should be noted that the discovery of the linkage between chlorine and the production of chlorinated disinfection by-products, most notably chloroform, was not made until 1974, and subsequent research has shown that there may be an association between those compounds and some cancer types. The association with the percentage of wastewater has not been confirmed in studies completed since 1974.

Other epidemiological work on microbiological contamination of water used for irrigation has been done in Israel; Lubbock, Texas; and Colorado Springs, Colorado, but no association was made with drinking water either directly or indirectly.

Whittier Narrows/Montebello Forebay, Los Angeles, California

Since 1962, SDLAC has been recharging the groundwater in the Whittier Narrows area of the San Gabriel River using a combination of reclaimed water, local runoff, and imported water. At that time, the limit on the amount of reclaimed water was 32,000 ac-ft per year (average 28 mgd); and during that period the actual recharge averaged 22,000 ac-ft per year (19 mgd) and comprised an average of 12.7 percent of the total recharge. In an attempt to increase the amount of reclaimed water in the recharge program, the SDLAC petitioned DOHS and the Los Angeles RWQCB, and agreed to formulate and conduct a health effects study. The study was initiated by the SDLAC in November 1978.

In the water quality characterization phase of the study, 223 wastewater samples collected from the four wastewater treatment plants (included in this study) were concentrated for virus assay. No viruses were detected in any of the disinfected tertiary effluent samples (dual media filtration); however, viruses were routinely isolated from non-disinfected wastewater samples. Median concentrations were:

- Unchlorinated primary effluent: 230-1,600 plaque-forming units per gallon (pfu/gal)
- Unchlorinated secondary effluent: 0.43-65 pfu/gal
- Unchlorinated filtered effluent: 0.52 pfu/gal

In the toxicology and trace organics phase of the work, the water extracted from the target wells in the distribution system was sampled and the data compared to all appropriate drinking water standards (Maximum Contaminant Levels [MCLs] and other short- and long-term "Action Levels"). None of the samples from the Montebello Forebay wells exceeded any of the standards referenced in the testing. In addition, none of the unchlorinated wells presented concern when evaluated in terms of any of the theoretical excess cancer risk models used in the study. Some of the chlorinated wells had some levels of trihalomethane (THM) that approached or exceeded the theoretical excess cancer risk for chloroform.

The examination of the general organic nature of the various surface and groundwater sources revealed that the range of the organic complexity followed this approximate order, from highest to lowest: surface water (including stormwater runoff); reclaimed water; imported surface water; and groundwater. The groundwater that is extracted in the Montebello Forebay is of higher quality than any of the recharge sources.

A survey of the organic residuals isolated from 90 samples for the presence of mutagenic organics (potential carcinogens) revealed mutagenic activity in at least one sample from each source. The level of activity or potency detected in various sample types followed this order, from highest to lowest: stormwater runoff, dry weather runoff, reclaimed water, groundwater, and imported water. In more than half of the instances observed, chlorination led to an apparent formation of mutagens. In the Montebello Forebay, no simple correlation was observed between percent reclaimed water in the wells and the observed mutagenic potency of residues isolated from the wells.

The authors concluded that..."In light of the results of studies described..., there is little concrete evidence to suggest that an imminent health hazard exists from current groundwater replenishment practices in the Montebello Forebay." They do conclude, however, that there is a need for continuing..."vigilance in the area of source management and control of some industrial organics (Ref. 2-14)."

The work done on epidemiology of the surrounding area and appropriate controls indicates that there is no identifiable impact from the recharge and subsequent extraction and consumption of reclaimed water. This opinion was formed following the examination of health and vital statistics data from 1969 to 1980 and a specific household survey to determine water consumption patterns in both the exposed population and the control area. The overall conclusions of the study were that..."Extensive evaluation of the Whittier Narrows groundwater replenishment project did not demonstrate any measurable adverse impacts on the area's groundwater or the health of the population ingesting this water." The study did not recommend additional epidemiology or human health effects work. SDLAC does have an ongoing well monitoring program for viruses.

The water quality analysis and toxicology work done in this study did not include animal testing but did have the advantage of human epidemiology from the exposed population.

Denver Water Board, Colorado

The Denver Potable Water Reuse Demonstration Project began in 1968 and included more than 10 years of pilot testing before the 1-mgd demonstration plant was designed. This plant began full operation in October 1985, and the work done to date includes more than 5 years of operation and testing, including health effects studies. The plant is now on standby status, and the completion of the analysis of the health effects testing is underway.

The demonstration plant included 10 major water purification processes that were used to treat the secondary effluent supplied by the Denver wastewater facility during the initial phase of the work:

- Lime clarification
- Recarbonation
- Pressure filtration
- Selective ion exchange for ammonia removal
- First stage activated carbon adsorption
- Ozonation
- Second stage activated carbon adsorption
- RO
- Air stripping
- Chlorine dioxide disinfection

Following the initial 2-year phase of the work, a final process stream was chosen for the second phase and the health-effects study. This included the following treatment processes:

- Lime clarification and recarbonation
- Pressure filtration
- Ultraviolet disinfection
- Activated carbon adsorption (42 minutes empty bed contact time)
- RO
- Air stripping
- Ozonation and chloramination for residual disinfection

These treatment processes promote the concept of multiple barriers in which several different processes may effectively remove or reduce the contaminants.

The final step in this process is a 2-year comprehensive health effects testing program. The program is designed to examine the long-term health effects of drinking reclaimed wastewater. It will also be used to compare the long-term health effects of drinking reclaimed wastewater to the effects of drinking the existing supply in Denver. Residual organics have been isolated from the process flow stream and fed to rodents. Testing includes a carcinogenicity study, and a reproductive toxicity study. The testing protocol is complete and data analysis is proceeding. Preliminary results indicate that no unusual health effects have been demonstrated from the reclaimed wastewater system. The animal testing has been completed, and the pathology is finished; data collection and verification is being finalized, and the contractor's report is expected in 1993.

This work did include full-scale animal testing using two species and full-life studies. This is the only full-scale animal testing study ever done on a water reclamation project.

At this time, the potable reuse project is not ready for implementation because additional water supplies are not yet needed for the City of Denver. When additional water supplies are needed, the Denver Water Board will evaluate all alternatives with respect to cost and treatment processes. Approval from the EPA and State Health Department will be sought before implementing the potable reuse project.

City of Tampa, Florida

In 1983 the City of Tampa, Florida, commissioned a study to evaluate the technical and economic feasibility of several alternative wastewater reuse projects, including indirect potable reuse. The plan includes two indirect reuse alternatives that provide blended raw water to the City of Tampa and the West Coast Regional Water Supply

Authority (WCRWSA) for further treatment before use in the domestic supply. The project recommendations include the following issues:

- Quantification of the water resource recovered from a collector well system along the bypass canal containing the treated effluent.
- Environmental studies on the effect of the wastewater plant effluent on the bypass canal and the Hillsborough River.
- Process evaluation for further treatment of the wastewater plant effluent to a quality suitable to match existing raw water supplies.
- Pilot-plant construction to evaluate the effects of lime treatment, two-stage recarbonation, filtration, GAC adsorption, RO, ultrafiltration, and disinfection on the wastewater effluent.

Construction of the pilot plant included four separate process trains with each train including lime addition, recarbonation, and filtration. The four trains that follow include:

- Chlorination only
- RO and chlorination
- Ultrafiltration and chlorination
- GAC adsorption and chlorination

Analytical testing of the four process streams was conducted to assist in choosing a process for the full health effects study. The testing program includes bacteria and protozoa, virus, chemical analysis, and toxicological concentration and evaluation. Bacteria, protozoa, and virus testing indicate that all process streams provide good removal, with the high lime treatment killing viruses before chlorination.

The toxicological testing program is being done in three phases: the first phase includes the Ames and DNA Damage screening tests done on all four of the process streams as well as the reference water (Hillsborough River). These data were used in selecting one of the process streams for the second stage of testing. At the end of the initial testing period, the process selected was GAC adsorption followed by ozone, rather than chlorination. Ozone was selected to replace chlorine because of the concern about chlorinated disinfection by-products.

The third stage health effects testing was conducted using the following testing protocol; the final results will be presented in 1993. The battery of tests included the following:

- Ninety-day subchronic toxicity to ensure that there are no toxicities associated with repeated exposure to the concentrated product that would not be shown from acute toxicity tests.
- Mouse Skin Initiation/Promotion to test for skin tumor promotion over a specified time period.
- Teratology testing to assess the possibility that materials present in the effluent might produce birth defects.
- Strain A Mice Lung Adenoma assay to assess carcinogenic activity with a short-term *in vivo* method.
- Reproductive effects study to establish effects on reproduction in the offspring of two successive generations.

The testing procedures have been completed, and preliminary results indicate that no problems are apparent in the effluent from the GAC/ozone pilot facility. The health effects advisory group is now reviewing the data, and report completion is expected in 1993.

City of San Diego, California

In 1985, the City of San Diego, California started a Health Effects Study (HES) in conjunction with numerous universities and state and local agencies (Ref. 2-15). The HES included analysis for infectious disease agents (bacteria, viruses, other pathogens) and chemical agents, and a baseline epidemiological study. The work was completed in 1991, and the final reports were presented to the City in 1992. The following is a summary of the findings of the HES.

Infectious Disease Agents. For 2-1/2 years, data were collected from the raw wastewater influent, the reclamation plant effluent, and the raw water that serves the City's Miramar water treatment plant. The data presented indicate that the reclamation plant effluent was equivalent to, or of better quality than, the Miramar raw water for total and fecal coliform, entrococcus, Salmonella, and virus. In that no viruses were detected in either the reclamation plant effluent or the raw Miramar supply, seeding studies were performed. Viruses were seeded in the range of 47,000 to 100,000 plaque-forming units per liter (pfu/l) and were not detected in any of the effluent samples from the reclamation plant. This indicates an apparent removal rate of as much as eight orders of magnitude.

Chemical Agents. Both the raw Miramar water and the reclamation plant effluent were chemically screened and monitored for 3 years. The data indicate that the concentrations of heavy metals were roughly equivalent in both supplies, and well below the drinking water standards. Measurement of trihalomethane formation potential (THMFP) in both supplies indicates that the Miramar supply is as much as 10 times greater than the reclamation plant effluent, and the TOC was approximately seven times higher in the Miramar supply (9.83 vs. 1.37 ppb). Phthalates (chemical plasticizers) were found in both supplies and in laboratory controls; this compound is not regulated, and frequently is found as a chemical contaminant in control samples.

Genetic toxicity testing and fish biomonitoring were also performed on both sources, and while both sources did exhibit some mutagenic activity, the reclamation plant effluent had less mutagenic activity than the raw Miramar source. The Miramar mutagenic activity may be caused by upstream chlorination of the water from Lake Skinner. The results of the fish biomonitoring were negative in all samples.

Overall analysis of the two sources indicates that they are approximately equivalent, with the reclamation plant effluent exhibiting higher quality in some areas.

Applicability to the City of San Jose

The three major studies listed previously all relate to the work proposed for the City of San Jose and the SCVWD. The recharge program in Los Angeles at the Whittier Narrows and Rio Hondo facilities most closely approximates the operation of the SCVWD percolation basins, and the distance and time of travel in the groundwater. The more recent demonstration work done by Denver and Tampa includes the additional treatment processes that are being investigated by San Jose. The health effects testing currently being completed by both of these agencies will provide valuable information to allow optimization of the testing being planned by San Jose. Both the Denver and the Tampa programs envision a more direct connection between the treatment and eventual domestic reuse, and the recharge operation being contemplated by San Jose will afford an extra "barrier" in the soil mantle not available to either Denver or Tampa.

Blue Ribbon Committee Comments

Dr. Bull thought that this project did not need to do animal testing, Ames testing, or any of the other surrogate tests but could instead rely on similar testing from other projects as discussed in this chapter. Dr. Bull also thought it would be useful to track chemicals that are used in the community and that might enter the San Jose WPCP. Mr. Lauer summarized the Denver potable reuse project experience with a similar chemical tracking program, noting that this type of pretreatment program did not account for chemicals produced or altered during use. Mr. Lauer recommended that this project design only a limited program to target particular chemicals of concern, and employ "challenge" testing with specific chemicals of concern (gasoline, TCE, etc.).

Preliminary work done with California DOHS has shown that they are comfortable with the process the City and SCVWD are using to date. DOHS representatives present at the Blue Ribbon Committee meeting expressed their satisfaction with the progress to date. No new information has been developed since that meeting, and no new regulatory requirements have been promulgated that would affect the proposed project.

Chapter 3
Aquifer Recharge

Chapter 3

Aquifer Recharge

This chapter updates information presented in the March 1990 Reconnaissance Investigation, outlines the recent effort to preliminarily estimate the impact of recharging reclaimed water into the Santa Clara Valley groundwater subbasin, and presents preliminary recommendations for additional work that will likely have to be undertaken before implementing a groundwater recharge project. Issues concerning groundwater recharge health effects and reclamation treatment requirements are addressed in Chapter 2. Chapter 1 summarizes the SCVWD facilities and water supply issues.

Introduction

The use of reclaimed water for aquifer recharge and eventual reuse is becoming increasingly popular in urban areas of the western United States. Reclaimed water is either discharged to surface facilities and allowed to percolate through the unsaturated zone to the water table or is injected directly into the aquifer below the water table. The reclaimed water (mixed with the local groundwater) is subsequently withdrawn, as needed, to augment existing water supplies.

Estimating the quantity of reclaimed water that could be recharged to the Santa Clara Valley groundwater subbasin is important for the following reasons:

- The SJ/SC WPCP may have to reduce the quantity of effluent it discharges to the South Bay; all or part of this reduction could be achieved with groundwater recharge.
- The quantity of recharge will affect the size and cost of the conveyance system and recharge facilities, and ultimately the cost of a project.

Santa Clara County overlays three interconnected groundwater subbasins, the Santa Clara Valley, Coyote, and Llagas subbasins. These groundwater basins are a vital component of the SCVWD water supply. The Santa Clara Valley subbasin currently provides an average of 150,000 ac-ft/yr of water to the County. The groundwater recharge project that is the subject of this report is focused on the Santa Clara Valley subbasin only; the Coyote and Llagas subbasins are in the distant and less populated southern end of the county. (The distances to the southern subbasins are too large to be cost effectively included in this groundwater recharge project.)

For this project, the quantity of reclaimed water that could be recharged to the Santa Clara Valley groundwater subbasin has been preliminarily evaluated in two ways: 1) at a local scale to evaluate whether or not the DOHS criteria could be met for three alternatives under steady-state conditions; and, 2) at a basinwide scale to begin evaluating what impact climatic variations and basin operations could have on recharge quantities through time.

In the remainder of this chapter, the following are presented: a summary of background information about the groundwater basin and its current operations; a description of the quantity of water evaluated for recharge; the approach, limitations and results from both the local and basinwide evaluations; and, recommendations for additional work. In addition, potential mitigation strategies that could be used to satisfy the DOHS guidelines (where the alternatives evaluated did not) are also presented. Appendices A and B present the technical details for the results presented in this chapter.

Background

Santa Clara Valley Groundwater Subbasin

Northern Santa Clara County is underlain by a thick section of sediments that range in permeability. The sediments were eroded from the surrounding hills and deposited in the ancestral San Francisco Bay and its margins. Typically, the sediments that were deposited near the hills are coarser-grained and more permeable; these sediments become progressively finer-grained and less permeable toward the bay. At some depths, the fine-grained, less permeable materials in the center of the basin are laterally continuous and are referred to as the "regional aquitard." Below this aquitard are more permeable sediments that yield large quantities of water; these more permeable zones of sediments are called "aquifers." The aquifer that lies beneath the regional aquitard is confined and is known as the "lower" or "confined aquifer." A low-yield, unconfined aquifer lies above the regional aquitard. The area within the boundary of the regional aquitard is known as the "confined zone." Outside the confined zone, no laterally continuous aquitard exists, and the thick wedge of sediments eroded from the surrounding hills is referred to as the "forebay region." The aquifer in this region is locally both unconfined and confined; it is known, however, as the "unconfined aquifer." The approximate boundary between the confined zone and the unconfined forebay region is illustrated on Figure 3-1. A schematic cross section through the northern Santa Clara Valley is shown on Figure 3-2.

Groundwater in the Santa Clara Valley subbasin generally flows from the southern portion of the basin, and from the recharge areas at the base of the surrounding hills, toward San Francisco Bay. Recharge of the deeper and more productive aquifers of the subbasin occurs primarily in the forebay region where the regional aquitard is not present; the existing SCVWD groundwater recharge facilities are located in the forebay region. The regional flow of groundwater is locally modified by discharges of groundwater from the basin; currently, pumping represents the largest discharge from the basin. On average, the groundwater subbasin yields approximately 150,000 ac-ft/yr

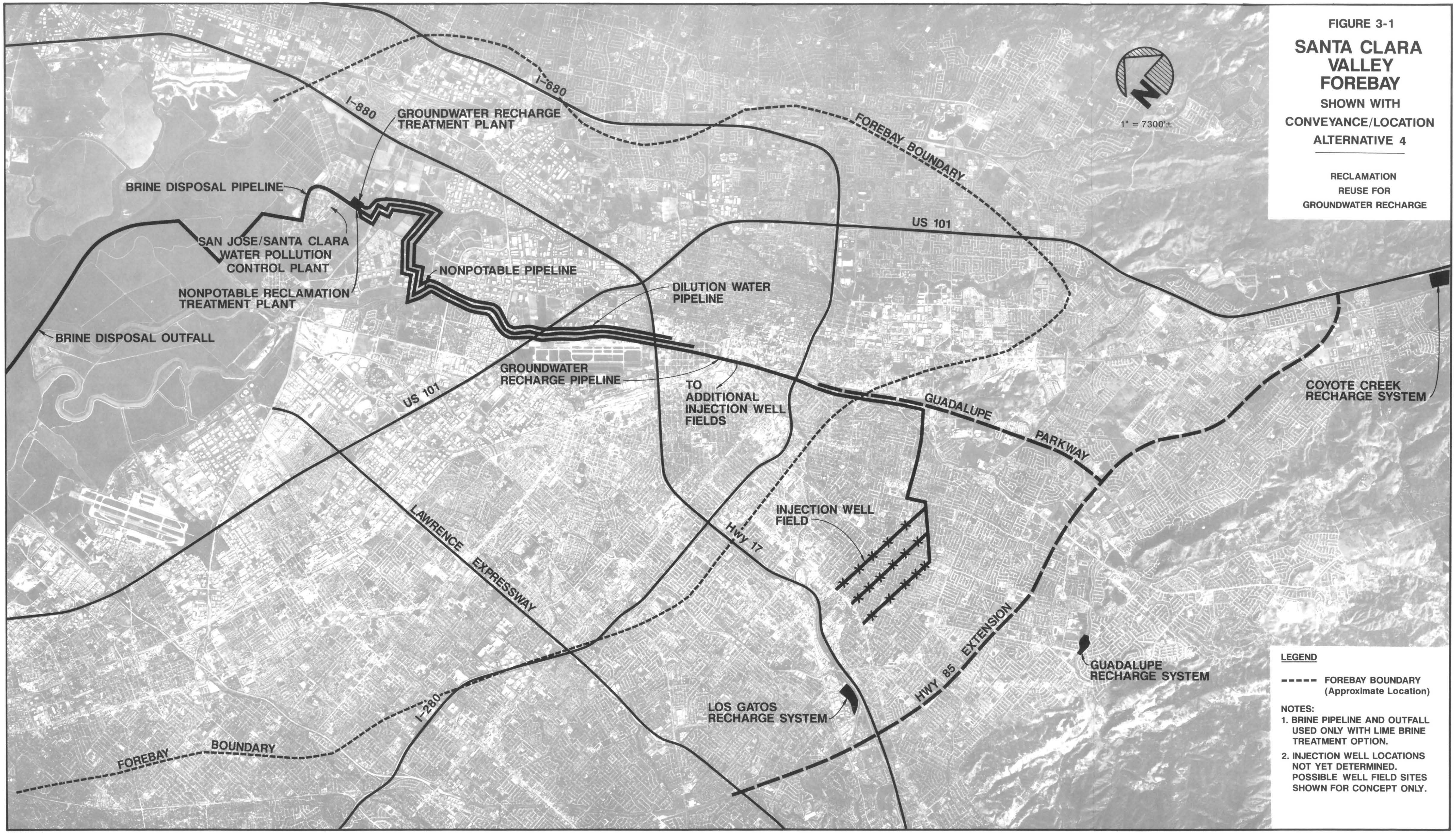

FIGURE 3-1

SANTA CLARA VALLEY FOREBAY

SHOWN WITH CONVEYANCE/LOCATION ALTERNATIVE 4

RECLAMATION REUSE FOR GROUNDWATER RECHARGE

1" = 7300'±
N
I-680
I-880
GROUNDWATER RECHARGE TREATMENT PLANT
FOREBAY BOUNDARY
BRINE DISPOSAL PIPELINE
US 101
SAN JOSE/SANTA CLARA WATER POLLUTION CONTROL PLANT
NONPOTABLE PIPELINE
DILUTION WATER PIPELINE
NONPOTABLE RECLAMATION TREATMENT PLANT
BRINE DISPOSAL OUTFALL
GROUNDWATER RECHARGE PIPELINE
TO ADDITIONAL INJECTION WELL FIELDS
US 101
GUADALUPE PARKWAY
COYOTE CREEK RECHARGE SYSTEM
INJECTION WELL FIELD
LAWRENCE EXPRESSWAY
Hwy 17
HWY 85 EXTENSION
GUADALUPE RECHARGE SYSTEM
LOS GATOS RECHARGE SYSTEM
I-280
FOREBAY BOUNDARY

LEGEND

- - - - FOREBAY BOUNDARY (Approximate Location)

NOTES:

1. BRINE PIPELINE AND OUTFALL USED ONLY WITH LIME BRINE TREATMENT OPTION.
2. INJECTION WELL LOCATIONS NOT YET DETERMINED. POSSIBLE WELL FIELD SITES SHOWN FOR CONCEPT ONLY.

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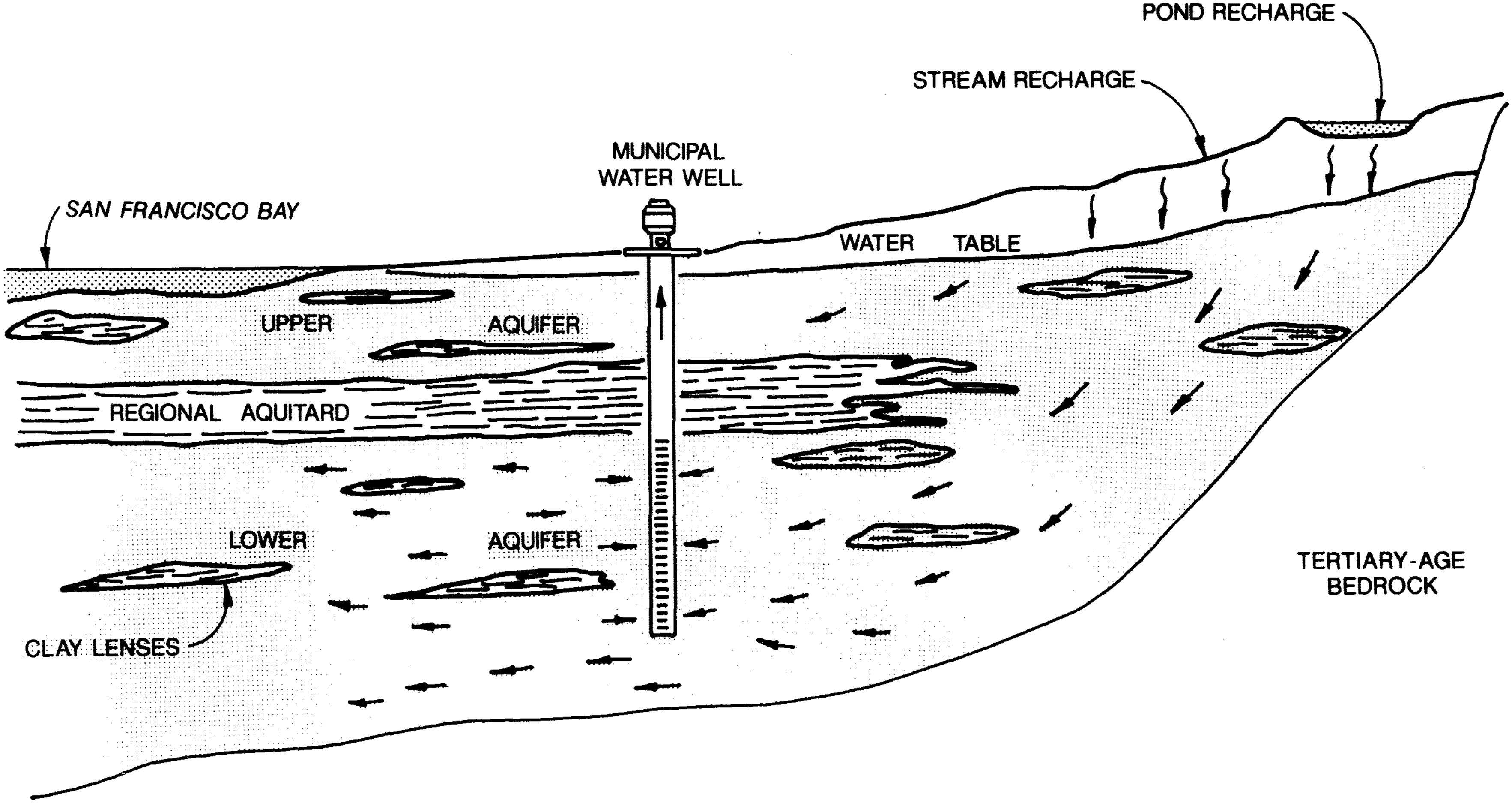

FIGURE 3-2

SCHEMATIC CROSS-SECTION OF THE GROUNDWATER BASIN IN THE SAN JOSE/SCVWD AREA

to pumping wells. Before the advent of significant groundwater pumpage in the basin, groundwater was discharged by upward movement of the groundwater under artesian conditions into the marshlands surrounding the San Francisco Bay.

Existing Groundwater Recharge System

SCVWD currently operates eight groundwater recharge facilities. Two of the recharge facilities are located in South County near Morgan Hill and Gilroy and were not considered while formulating the groundwater recharge alternatives because of the high cost of conveyance facilities. Of the six located in the north county, three recharge facilities have a relatively small capacity and were also not considered economical for recharging reclaimed water because of the high conveyance costs. Thus, only the three largest recharge facilities in North County were considered for use in the groundwater recharge project; the Los Gatos Creek, Guadalupe River, and Coyote Creek facilities. The locations of the recharge facilities in North County are shown on Figure 3-1.

Recharge of water to the groundwater basin occurs both naturally through infiltration and artificially through the recharge facilities operated by the SCVWD. A major source of water for the artificial recharge is the local surface water runoff that occurs during the winter months. This water is stored in a number of local reservoirs and is later discharged to the system of onstream and offstream recharge ponds and to several major surface streams. These discharges of the stored water recharge water to the groundwater basin. When needed, recharge of the groundwater basin by local runoff water is augmented by imported water. To enhance in-stream recharge, temporary gravel dams are erected between late spring and early summer to hold water. These dams are removed before winter to allow for the passage of flood waters.

The three groundwater recharge facilities that were considered when formulating groundwater recharge alternatives are located in the forebay region of the Santa Clara Valley Subbasin (where the regional aquitard is not present). Water from these facilities recharges the lower aquifers, where most of the pumping occurs. Recharge to the groundwater system that occurs bayward of the forebay region/confirmed zone boundary does not recharge the lower aquifers and, consequently, does not significantly contribute to the local groundwater supply.

The total capacity of the six recharge facilities located in the Santa Clara Valley groundwater subbasin is approximately 113,000 ac-ft/yr. Of this total capacity, the three major facilities (Los Gatos Creek, Guadalupe River, and Coyote Creek) have a combined capacity of 89,000 ac-ft/yr (Table 3-1). Because this combined capacity comprises a significant portion of the total system capacity, and because the Los Gatos Creek, Guadalupe River, and Coyote Creek facilities are close to potential reclaimed water pipeline alignments, only the Los Gatos, Guadalupe, and Coyote systems were considered during alternatives development. The remaining recharge capacity is located in smaller ponds that would require high conveyance costs for a relatively small recharge quantity.

The annual recharge quantities for each of the three larger recharge systems (Los Gatos Creek, Guadalupe River, and Coyote Creek) are shown in Table 3-1. These annual recharge quantities were determined by SCVWD staff using field measurements and historical recharge data. These quantities reflect the maximum capacities of these systems based on the availability of an unlimited water supply and the current operation and maintenance program. Table 3-1 also presents a "practical" annual total capacity of 68,000 ac-ft/yr for the three facilities. It is this "practical" capacity that is used in the local-scale analyses discussed in the following paragraphs.

Table 3-1
Recharge System Capacity

Recharge Facility	Total Annual		Practical Recharge Water Annual Capacity[a]		
	Capacity (ac-ft/yr)	**Total (mgd)**	**Total (ac-ft/yr)**	**Total Recharged Water (mgd)**	**Total Reclaimed Water[c] (mgd)**
Los Gatos Creek	42,000	37.5	33,000	30	15
Guadalupe River	27,000	24.1	16,000	14	7
Coyote Creek	20,000[b]	17.9	19,000	17	8
Total	89,000	79.5	68,000	61	30

[a] Reflects capacity of recharge ponds economically accessible by reclaimed water conveyance pipelines, excluding in-creek recharge/flowback.

[b] The 1990 Reconnaissance Report indicated that the Coyote recharge system had a capacity of 43,000 ac-ft/yr. This capacity has been revised to 20,000 ac-ft/yr because the earlier amount included capacity to recharge Llagas and Coyote subbasins.

[c] Reclaimed water quantity if the recharge water is assumed to be 50 percent reclaimed water and 50 percent dilution water (the need for this 50/50 blend is discussed in the following sections).

Recharge Quantity

The quantity of water that can be recharged to the Santa Clara Valley subbasin is constrained by regulations and basin operations. These constraints are discussed in the following paragraphs. Evaluation of the regulatory constraints is the subject of the local scale analyses described in subsequent sections and in Appendix A.

Regulatory Constraints

The proposed DOHS criteria for the recharge of reclaimed municipal wastewater (March 2, 1992) contain several minimum requirements that could potentially limit the quantity of reclaimed water that can be recharged at a particular facility. These are:

- Minimum depth to groundwater beneath a surface recharge facility.

- Minimum retention time of the reclaimed water in the aquifer and the minimum horizontal separation between a reclaimed water recharge point and the nearest water supply well

- Maximum reclaimed water contribution; the maximum percentage of reclaimed water pumped from the nearest water supply well.

The implications of each of these criteria is discussed in the following paragraphs.

Minimum Depth to Groundwater. The minimum depth to groundwater requirement of 10 to 20 feet potentially limits the quantity of reclaimed water that can be applied at a surface recharge facility (these criteria do not apply to injection facilities because the reclaimed water is injected directly into the local groundwater). As water percolates downward from a recharge basin, it creates a local region of elevated groundwater levels, or a "mound," in the regional water table. These higher water levels beneath the recharge basin provide the necessary driving force to move the additional water away from the basin. The larger the quantity of water applied to the basin, the higher the groundwater mound.

In addition to the quantity of water recharged, the height and extent of the mound also depend on the ability of the aquifer to transmit water away from the ponds; ie., the transmissivity of the aquifer. Aquifer transmissivity is dependent on the basin sediments (soil conditions); aquifers with lower transmissivities will not transmit as much water away from the groundwater mound as those with higher transmissivities (and the mound therefore remains higher).

Minimum Retention Time and Horizontal Separation. The DOHS criteria specify a minimum retention time for reclaimed water in an aquifer of 6 months for a surface recharge facility and 12 months for an injection facility. Coupled with these retention times are minimum horizontal separation distances of 500 feet and 2,000 feet for surface recharge and direct injection recharge, respectively. Retention time and horizontal separation are a function of the distance to the nearest water supply well and the speed at which the groundwater moves towards the well. These requirements may limit the quantity of water that may be applied to spreading basins or injected through wells. For both surface recharge facilities and injection facilities, a local mound is created (the height and extent of which depend on the quantity of water recharged and the transmissivity of the aquifer). As the height of the groundwater mound beneath a recharge basin or injection well field increases, the horizontal hydraulic gradient between the area where recharge is occurring and the nearby production wells also increases. Because groundwater velocity is directly proportional to the horizontal hydraulic gradient, this increased hydraulic gradient will increase groundwater velocities and reduce the residence time of the reclaimed water in the aquifer.

Maximum Reclaimed Water Contribution. Another DOHS requirement specifies the maximum allowable reclaimed water contribution that can be pumped from nearby water supply wells is 20 to 50 percent depending on the treatment method, the reclaimed water quality, and the type of recharge facility. The fraction of reclaimed water that enters a well near a recharge source depends on the reclaimed water dilution before recharge, the relative location of the recharge area to the pumping wells, the regional horizontal hydraulic gradient, and the pumping well construction (e.g., whether or not the well is screened in approximately the same interval where the reclaimed water will be). A well-by-well analysis will be needed to estimate this fraction for a given recharge alternative. By specifying a maximum fraction of reclaimed water that may be pumped from water supply wells, the quantity of reclaimed water that can be recharged may be limited.

Exceptions. The draft DOHS regulations state that "Alternatives to the recharge site requirements specified in Section 60320.05 or treatment performance standards specified in Section 60320.03 shall be accepted if the project sponsor demonstrates and documents the proposed alternative reliably achieves an equal degree of public health protection." Based on this statement, a survey of ongoing projects, and preliminary discussions with DOHS, if site conditions do not meet one of the explicitly defined criteria, it may be possible to develop an engineered alternative to satisfy DOHS concerns.

Operational Constraints

Several operational constraints may impact the quantity of reclaimed water that be could be recharged to the aquifer. The first potential operational constraint is demand. Preliminary indications from the SCVWD Master Plan update (scheduled to be completed in 1992) are that SCVWD will need an additional 15,000 ac-ft/yr for water supply from the groundwater by the time the county is "built out." SCVWD staff have stated that this average demand may be met through the year 2020 by a combination of conservation, water transfers, and increased nonpotable reuse of reclaimed water. During periods of drought, however, the groundwater demand may increase.

Another potential operational constraint is the availability of local or import water during extreme weather conditions. During drought years, there may be an insufficient amount of local or import water available for diluting reclaimed water. During very wet years, however, there may be an abundance of local water. If, during such wet years, reclaimed water is recharged instead of local water, the augmented stream flows associated with the diverted local water may increase the potential for flooding downstream. New recharge facilities (either surface or injection) would provide additional flexibility to recharge in a wet year. At this time, however, the addition of new surface recharge facilities is not being considered because of the large land requirements and the difficulty of siting such a facility.

A third operational constraint is the potential impact of reclaimed water quality on surface recharge facility operations. If the reclaimed water quality had a high sodium content or a high sodium adsorption ratio, there is a possibility that the sodium could combine with negatively charged clay ions and decrease the recharge capacity. Or, if the SCVWD had to began a fill/empty cycle to maintain an aerobic layer on the pond bottom, such operational changes could reduce the capacity. Furthermore, if the reclaimed water quality differed greatly from that of the native groundwater, then leaching of minerals from the subsurface soils could also occur. At this time the reclaimed water quality is projected to be such that no operational changes should be necessary.

Local Scale Evaluation

Based on the preliminary analyses conducted for the March 1990 Reconnaissance Report, three alternatives for recharging the groundwater basin with reclaimed water were chosen for evaluation against the DOHS criteria discussed in the previous section:

- Injection of reclaimed water into the unconfined aquifer through new wells located in the forebay region
- Recharge of reclaimed water to the unconfined aquifer through the existing Los Gatos Creek, Guadalupe River, and Coyote Creek recharge facilities (a quantitative evaluation was conducted only for the Coyote Creek system; see Appendix A)
- Injection of reclaimed water to the confined aquifer through new wells located near the SJ/SC WPCP (the incentive for evaluating this alternative was the potentially lower conveyance costs)

The following paragraphs describe the methodology that was used to evaluate each of the recharge alternatives, as well as the assumptions, limitations, and results (and their accuracy). Technical details of the modeling are contained in Appendix A.

Forebay Injection Alternative

This alternative consists of an injection well field in the forebay area where the aquifer is unconfined (Figure 3-3). The area between the Guadalupe River and Los Gatos Creek recharge facilities was selected as a potential site because of its relatively high aquifer transmissivity, its lower local groundwater levels, and its proximity to the reclaimed water pipeline alignment along the Guadalupe River corridor. A drawback of this alternative is that although recharging significant quantities of reclaimed water through an injection facility in the forebay region may be theoretically feasible, there is no operational history of such injection in the Santa Clara Valley.

The forebay injection alternative was evaluated by first gathering the available information on aquifer properties, well locations, and pumping rates near the potential injection site. The existing conditions were simulated using an analytical model. This

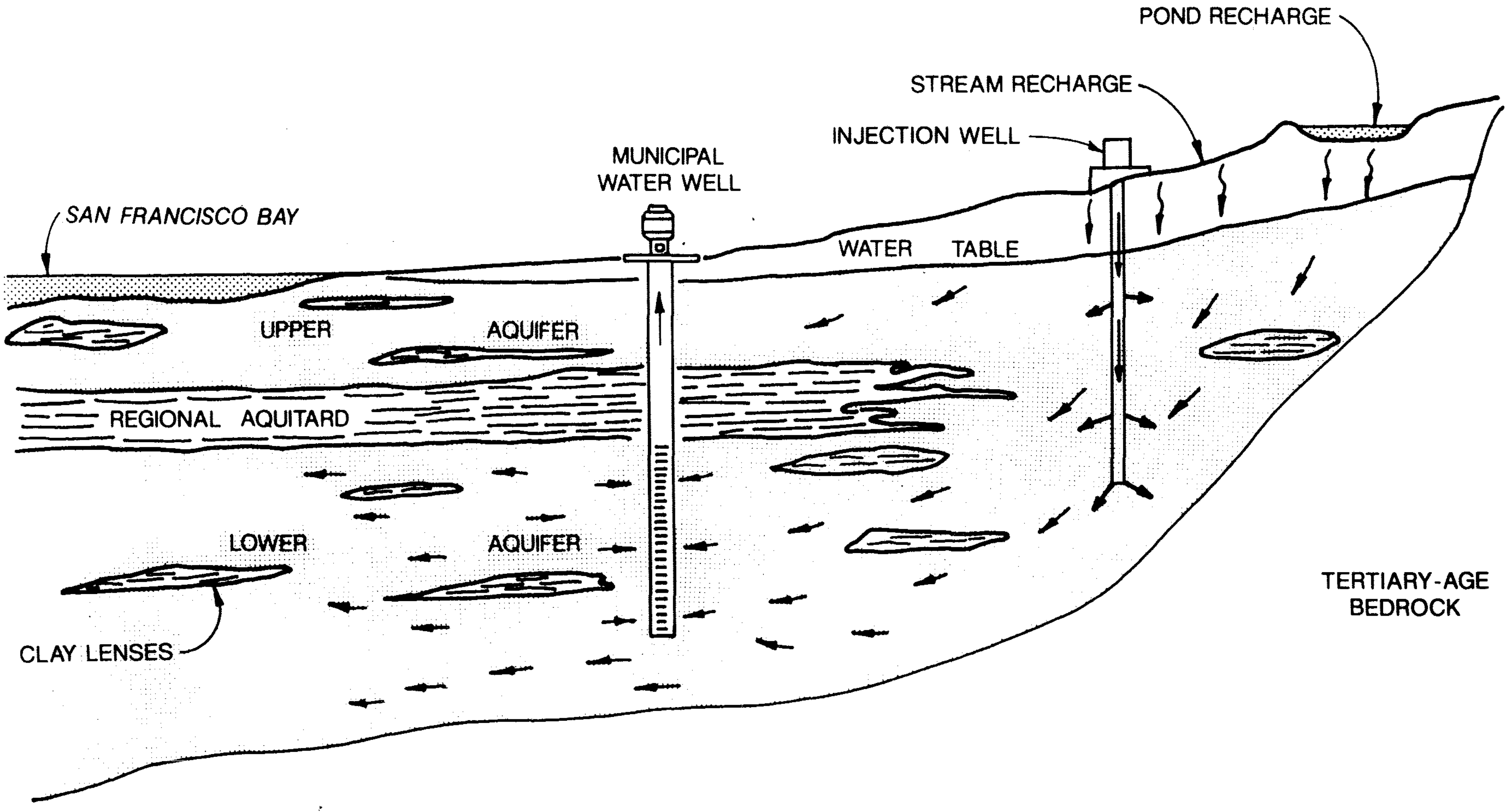

FIGURE 3-3

INJECTION WELL CONCEPT
IN THE FOREBAY

model was then used to simulate the three-dimensional head distribution that would result from implementing the injection well alternative. From the resulting head distribution, groundwater flow directions and velocities were estimated and used to evaluate whether or not the DOHS criteria would be met if the alternative was implemented. The details of the methodology followed are presented in Appendix A; the results are presented later in this section in summary tables and paragraphs (following the description of the alternatives).

The accuracy of the results from the analyses is limited mainly by the accuracy of the input data. For instance, the estimate of the most sensitive aquifer parameter for these calculations, transmissivity, is based on few data and may vary by a factor of two. Using professional judgement, the results of the analyses are estimated to be within 50 percent.

Surface Recharge Alternative

The surface recharge alternative consists of recharging reclaimed water to the unconfined aquifer through the three largest spreading facilities in North County (Los Gatos Creek, Guadalupe River, and Coyote Creek). The recharge rates would be the same as those under which the facilities are currently operating. The benefit of this alternative is that, because the facilities are already operating, there is less uncertainty in the success of their operational capacity (as compared to the injection alternatives). For the purposes of the current evaluation, a surface recharge facility was defined as the offstream and onstream ponds; not the adjacent surface stream reaches that could allow flowback of reclaimed water (and thus potentially require that the DOHS criteria be evaluated for the entire creek length).

The surface recharge alternative was evaluated by compiling existing data and constructing an analytical model for the Coyote Creek facility only. Following the same methodology used to evaluate the forebay injection alternative, the three-dimensional head distribution that would result from recharging at the Coyote Creek facility was simulated. The resulting groundwater velocities and residence times were then evaluated against the DOHS criteria. The accuracy of the results from this evaluation is limited by the accuracy of the input data (the same accuracy as presented for the injection alternatives).

Confined Aquifer Injection Alternative

This alternative comprises an injection well field with wells in the deeper aquifer near the SJ/SC WPCP (Figure 3-4). The potential benefits of this alternative are that the short conveyance distance of the reclaimed water would result in lower conveyance costs, and the potential for injecting increased percentages of reclaimed water is higher because the area is downgradient of the major water supply wells. The limitation of this alternative is that groundwater elevations in the deep aquifer near the WPCP are

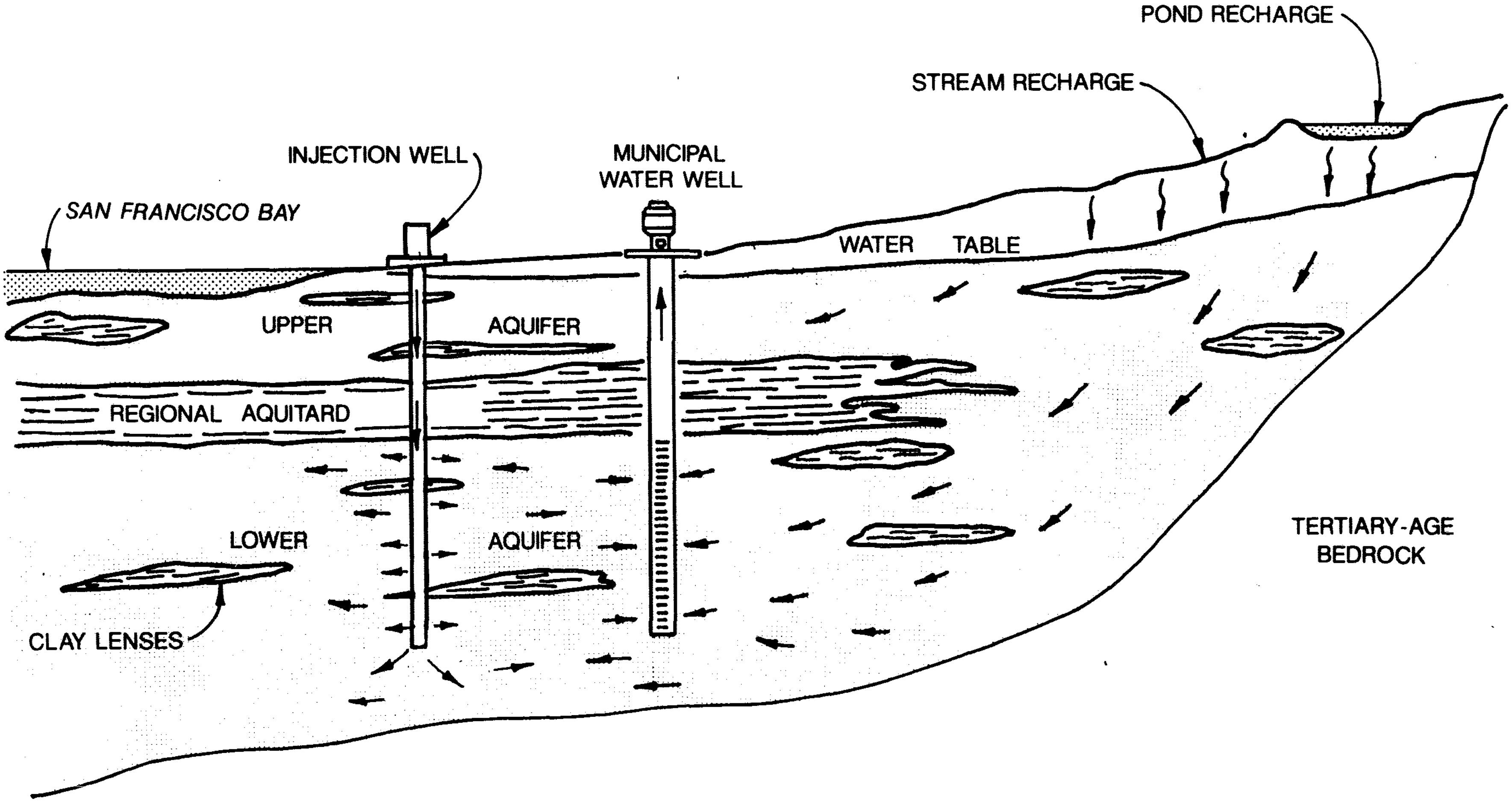

FIGURE 3-4

INJECTION WELL CONCEPT
NEAR THE SAN FRANCISCO BAY

at about sea level ("full"), and therefore it is unlikely that large quantities of water can be injected at this location.

The methodology followed to evaluate this alternative was the same as that described for the Forebay Injection Alternative.

Results

The results of the local scale evaluations are summarized in Table 3-2 (the technical details of the analyses are presented in Appendix A). As shown, the results indicate that none of the alternatives (Coyote Creek facility assumed to be representative of the surface recharge facility, the confined aquifer injection, or the forebay injection) meet all of the DOHS criteria at the nearest water supply well when 100 percent reclaimed water is recharged. In addition, the Coyote Creek facility may not satisfy DOHS' minimum depth to groundwater criterion at all times. As shown in Table 3-2, between one and 21 wells would be impacted by implementing one of the recharge alternatives.

As noted in Table 3-2 and discussed previously, the analyses conducted were preliminary; the results are therefore estimates that have limitations on their accuracy. For purposes of this report, professional judgement was used to estimate the accuracy of the results. For example, in Table 3-2, the calculation for residence time is shown to have an accuracy of approximately ±50 percent.

Because many of the DOHS criteria were not met by the alternatives evaluated, several mitigative measures were identified that would allow the alternatives to meet the criteria:

- Retention Time: increase the target retention time beyond that required by the DOHS criteria by the estimated error in the retention time calculation. With an estimated error of 50 percent, this means increasing the target minimum retention time from a minimum of either 6 or 12 months (surface or direct injection recharge, respectively) to a minimum of 9 or 18 months. This increase in retention time results in an additional 0 to 5 wells that must be abandoned in order to comply with the new target retention time.

- Minimum Horizontal Distance: wells that fall within the minimum horizontal distance could be abandoned.

- Maximum Reclaimed Water Contribution: combine reclaimed water and dilution water to a 50 percent reclaimed water blend above ground, prior to recharge.

Table 3-3 presents a summary of a reevaluation of the three alternatives against the DOHS criteria if the mitigative measures were implemented.

Table 3-2
Local Models Task DOHS Criteria Evaluation

				Does Alternative Satisfy DOHS Critieria For:					
Alternative	**Total Recharge Quantity (±50%)**	**Number of Injection Wells**	**Injection Well Spacing**	**Retention Time[a] (50%)**	**Minimum Horizontal Distance[b]**	**Maximum Reclaimed Water Contribution[c] (±30%)**	**Depth to Groundwater (±50%)**	**Number of Wells Out of Compliance**	**Uses[d]**
Confined Zone Injection	2.8 mgd	10	1,200-1,500 ft	Yes	No	No	--	13	U
Forebay Injection	25 mgd	12	2,000 ft	Yes	Yes	No	--	1	U
	30 mgd	16	4,000 ft	No	No	No	--	17	M,U
	35 mgd	20	6,000 ft	No	No	No	--	116	NE
Coyote Facility	18 mgd	N/A	N/A	No	No	No	Unknown[e]	21	U

Notes: Error estimates listed below each category where applicable; basis of error estimate is professional judgement.

-- = No depth to groundwater DOHS criteria proposed for direct injection projects

[a] DOHS Minimum Retention Time Criteria: 6 months - Surface Recharge; 12 month - Direct Injection

[b] DOHS Minimum Horizontal Distance Criteria: 500 Feet - Surface Recharge; 2,000 Feet - Direct Injection

[c] DOHS Maximum Reclaimed Water Contribution: 50 percent - Assuming reclaimed water which has been oxidized, filtered, disinfected and subjected to organics removal and which meets groundwater nondegradation standards (TOC of 1 mg/l).

[d] Well Use Codes: M = Municipal U = Unknown NE = Not evaluated

[e] The DOHS criterion is either 10 or 20 feet, depending upon the initial percolation rate. Based on the preliminary results discussed herein, it appears that the depth to water is between 10 and 20 feet.

Table 3-3
Mitigated DOHS Criteria Evaluation

				Assuming Wells Abandoned; Does Alternative Satisfy DOHS Criteria For:						
								Abandoned Wells		
Alternative	**Total Recharge Quantity (±50%)**	**Number of Injection Wells**	**Injection Well Spacing**	**Retention Time[a]**	**Minimum Horizontal Distance[b]**	**Maximum Reclaimed Water Contribution[c]**	**Depth to Groundwater (±50%)**	**Number**	**Uses[d]**	**Total Capacity (ac-ft/yr)[e]**
Confined Zone Injection	2.8 mgd	10	1,200-1,500 ft	Yes	Yes	Yes	--	13	U	NE
Forebay Injection	25 mgd	12	2,000 ft	Yes	Yes	Yes	--	1	U	0.1
	30 mgd	16	4,000 ft	Yes	Yes	Yes	--	17	M,U	1,200
	35 mgd	20	6,000 ft	Yes	Yes	Yes	--	>116[f]	NE	NE
Coyote Facility	18 mgd	N/A	N/A	Yes	Yes	Yes	Unknown[g]	26	U	200

Notes: Error estimates listed below each category where applicable; basis is professional judgement.
-- = No depth to groundwater DOHS criteria proposed for direct injection projects

[a] Mitigated DOHS Minimum Retention Time Criteria: 9 months - Surface Recharge; 18 month - Direct Injection
[b] Mitigated DOHS Minimum Horizontal Distance Criteria: 500 Feet - Surface Recharge; 2,000 Feet - Direct Injection
[c] Mitigated DOHS Maximum Reclaimed Water Contribution: 50 percent - Assuming reclaimed water has been oxidized, filtered, disinfected and subjected to organics removal. Assuming reclaimed water quality meets groundwater nondegradation standards (TOC of 1 mg/l). Recharge water is assumed to be 50 percent reclaimed water and 50 percent dilution water; blended prior to recharge.
[d] Well Use Codes: M = Municipal U = Unknown NE = Not evaluated
[e] Approximate total pumping capacities based on maximum year mean pumpage 1985-1990 or 1970-1990. Data were not available for a number of wells to be abandoned.
[f] Increased number of wells not estimated.
[g] The DOHS criterion is either 10 or 20 feet, depending upon the initial percolation rate. Based on the preliminary results discussed herein, it appears that the depth to HLO is below 10 and 20 feet.

Based on the analyses conducted to date and by implementing the mitigative measures outlined above, 20 mgd of reclaimed water (40 mgd of total recharge water) could be recharged into the Santa Clara Valley subbasin using direct injection or possibly surface recharge methods while meeting the DOHS regulatory requirements. The following assumptions and limitations apply:

- Dilution and reclaimed water are assumed to be blended to a 50/50 mixture before recharge, and the minimum residence times are assumed to be 150 percent of the DOHS standard (18 months minimum instead of 12 months minimum). The 50 percent reclaimed water blend above ground meets the DOHS criterion for the maximum allowable reclaimed water concentration in the nearest well before recharge. Increasing the residence time accounts for the potential error in residence time estimates.

- Surface recharge at Coyote Creek could be accomplished, but 26 wells (with a total capacity of approximately 200 ac-ft/year or 0.2 mgd) around the facility would need to be abandoned (Table 3-3). These wells would not meet the DOHS criteria for minimum horizontal distance or for minimum residence time.

  Well data, including type and capacity, is based on information originally supplied by the SCVWD. Based on data from 1985 through 1990, capacity data were available for 18 out of the 26 wells which would need to be abandoned. Because the well uses were not available, it was assumed that all wells are potable wells. This would lead to a maximum abandoned capacity of approximately 200 ac-ft/yr. If maximum pumpage data from the period 1970 through 1985 were included, the total abandoned capacity estimate would increase to approximately 2,100 ac-ft/yr.

  The minimum depth-to-groundwater appears to be 10 to 15 feet and thus the minimum 20-foot criterion may not be met. Similar estimates for the Los Gatos and Guadalupe recharge facilities were not in the scope of this study. The DOHS and RWQCB might be persuaded to disregard the depth to groundwater requirement because the reclaimed water meets direct injection water quality standards. In this case, additional water supply wells might need to be abandoned if the surface recharge facility were made to meet the direct-injection DOHS minimum horizontal separation criterion of 2,000 feet.

- Direct injection of reclaimed water in the forebay area appears feasible. A well field of approximately 12 wells over an area 4,000 feet by 6,000 feet, could inject approximately 12.5 mgd of reclaimed water or 25 mgd of total recharge water while requiring that one water supply well be abandoned. The well to be abandoned has a 60-gallon per day (gpd) capacity (0.06 ac-ft/year). As an approximate upper limit on recharge quantity, the same location could accept approximately 15 mgd of reclaimed water or 30-mgd total, by injecting through 16 wells over a 12,000 feet by 12,000 feet area, while requiring that 17 water supply wells be abandoned with an approximate combined pumping capacity of approximately 1.1 mgd (1,200 ac-ft/year).

Well data, including type and capacity, are based on data base information originally supplied by the SCVWD. Based on data from 1985 through 1990, capacity data were available on 1 out of the 1 well which would need to be abandoned in the 25-mgd recharge case. Capacity data were available on 8 out of the 17 wells which would need to be abandoned in the 30-mgd recharge case. Use type information was available for only three of these wells, and so to assess a worst case, it was assumed that all wells are potable wells. This would lead to a maximum abandoned capacity of approximately 900 ac-ft/yr. If maximum year data from the period 1970 through 1985 is included, the total abandoned capacity estimate for the 30-mgd case increases to approximately 1,200 ac-ft/yr, with capacity data now available on 17 out of the 17 wells to be abandoned.

A separate well field(s) with 7 direct injection wells would be used to recharge an additional 15 mgd of recharge water to make up the 40-mgd total. The groundwater model simulations indicate that this additional 15 mgd can likely be recharged into the basin. Evaluation of these injection wells for DOHS criteria was not included in the scope of this study.

- Direct injection of significant quantities of reclaimed water near SF Bay and SJ/SC WPCP does not appear to be practical. As indicated in Tables 3-2 and 3-3, the confined zone injection is limited to approximately 2.8-mgd total recharge using 10 direct injection wells in the one area considered. This is thought to be approximately representative of other areas at the same depth in the confined zone.

- Surface recharge or direct injected reclaimed water may be used to supplement local or import water presently used for recharge

- In extremely dry years, lack of available dilution water may limit the ability to recharge reclaimed water by either surface or direct injection

- In extremely wet years, lack of recharge capacity may limit the ability to recharge reclaimed water by surface spreading

Estimates of the accuracy of the above results depends on the parameter in question and the recharge method. With the above assumptions, the accuracy errors are mitigated or accounted for.

Recommendations for additional work that will need to be completed before a groundwater recharge project is designed and built include:

- Collect site-specific data, including depth to groundwater, hydraulic parameters (transmissivity, storativity, and porosity), and groundwater quality (particularly in the direct injection well field area if the project proceeds as a direct injection recharge project)
- Conduct additional local model studies of the Los Gatos Creek and Guadalupe River surface recharge facilities (if the project proceeds based on surface recharge)
- Field check nearby wells locations, well status, well construction, well use, and production capacity
- Conduct specific transient groundwater flow calculations using an enlarged version of the basinwide model with an attached particle-tracker
- Pilot test an injection well

Basinwide Scale Evaluation

The basinwide groundwater model was used to begin investigating the effect of forebay injection on the basinwide groundwater levels given different climatic conditions and timeframes. This abbreviated investigation can not determine the definitive effect of injecting water into the subbasin, but it does provide insight into the basin's response to injection. The technical details of the modeling conducted is contained in Appendix B. In this section, an overview of the methodology is presented, and the preliminary results summarized.

Two basinwide groundwater model simulations were run based on two sets of inputs, including forebay direct injection totaling 40 mgd (20 mgd of reclaimed water and 20 mgd of dilution water). Adding additional recharge to the basin through injection will raise groundwater levels across the basin, given current extraction pumping rates. Water levels that rise too high may cause damage to existing structures or infrastructures.

Groundwater levels projected by the two scenarios were checked at 17 locations around the basin. The 17 locations correspond to 17 well locations where the groundwater model was calibrated. Projected hydrographs were plotted and compared to a water level standard. The chosen water level standard is the higher of either 25 feet below ground surface, or the maximum groundwater level recorded in the last 15 years at that well. This standard was used as a measure of the maximum acceptable groundwater level at each well, although additional work is required to accurately define the actual maximum acceptable level for each location.

Simulation 1 simulated 5 years of average pumping and hydrological conditions, historical maximum surface recharge, average initial groundwater levels, and 40-mgd forebay direct injection (25 mgd between Los Gatos and Guadalupe Creeks, 15 mgd in Santa Teresa Basin).

Simulation 2 simulated 8 years, with 3 years of average conditions followed by 5 years of wet conditions. The first 3 years of simulation 2 were based on average pumping and hydrological conditions, average surface recharge, average initial groundwater levels, and 40-mgd forebay direct injection (25 mgd between Los Gatos and Guadalupe Creeks, 15 mgd in the basin northwest of Los Gatos Creek). The last 5 years of simulation 2 were based on average pumping, wet hydrological conditions, maximum surface recharge, and 40-mgd direct injection (25 mgd between Los Gatos and Guadalupe Creeks, 15 mgd in the basin northwest of Los Gatos Creek).

The groundwater modeling simulations results must be interpreted with caution. These results are based on only two sets of input, even though there are many combinations of input which might provide different results. These two simulations provide general results for specific sets of circumstances. Different initial assumptions regarding direct injection, surface recharge, pumping, and hydrological conditions will result in groundwater level predictions different from those calculated by the first two simulations. Additionally, there may be other simulations which might provide more realistic groundwater level predictions. The two simulations represent only average and wet conditions, and do not include periodic droughts. Finally, there are errors in the model which are difficult to quantify. Based on previous calibrated model runs, this error is probably less than 25 percent. It is important to note that because of grid/scale limitations these groundwater model simulations do not specifically investigate compliance with proposed DOHS criteria. The groundwater model simulations constitute only the most cursory look at potential effects of additional recharge. Additional field data collection and modeling must be conducted prior to implementing a groundwater recharge program. Recommendations for additional modeling are presented in the paragraph following the results summary.

The results of these simulations can be summarized as follows:

- Results from the two simulations indicate that it is feasible to recharge 20 mgd of reclaimed water. These results are based on the simulation input conditions only, with properly placed direct injection wells, assuming that some water supply pumping wells are redistributed to the forebay area near the direct injection wells. The redistributed pumping wells would reduce the localized high groundwater conditions caused by the direct injection. Additional unknowns not accounted for in these model, such as actual soil conditions or water chemistry, may alter these results.

- The areas between Los Gatos Creek and Guadalupe River and north and west of Los Gatos Creek appear to be more promising for direct injection of large quantities of water then the Santa Teresa Basin. The Santa Teresa Basin may be useful for direct injection of smaller quantities of water.

- In Simulation 2, many of the hydrographs (water level plotted versus time) show a slight rise in the first three average condition years, an increased water level rise rate during the next 4 years of wet weather conditions, but then a decrease in rise rate during the fifth consecutive wet year. This suggests that groundwater levels will rise under average conditions, rise faster under wet conditions, but may begin to level off as the basin approaches an equilibrium condition, possibly before becoming 'full.'

- Hydrographs suggest that the Santa Teresa Basin is not directly influenced by the injection wells in the other parts of the basin west of Guadalupe River. It appears that groundwater levels exceeding the maximum acceptable level are due only to high natural recharge in wet years.

- Water levels in many parts of the basin rise under average conditions, but do not reach the maximum groundwater levels.

- Water levels in several areas of the basin rise under five consecutive wet year conditions to the maximum groundwater levels. In the confined zone, the five wet years result in greater pressures under the aquitard, rather than actually increasing groundwater levels near the ground surface. In the forebay downgradient from the injection wells, the five wet years result in local mounding above the maximum acceptable groundwater level. In the Santa Teresa Basin, the five wet years result in groundwater levels above the maximum acceptable due most likely to wet weather, not because of direct injection recharge.

  Adding additional water supply wells near areas of local mounding could prevent unacceptably high local groundwater levels. The additional water supply wells could be additional pumping capacity or relocated pumping capacity.

Based on the results of the preliminary basinwide analyses, additional simulations are recommended where most of the model input parameters are held constant while only one or two factors are varied (compared to the two simulations run to date where several parameters were varied). Objectives for recommended additional simulations include:

- Estimate the number of consecutive average climate years before the basin reaches the maximum acceptable level given different pumping and recharge conditions.

- Evaluate locating new water supply wells in the forebay near localized high groundwater levels to prevent the groundwater from exceeding the maximum acceptable level, while also meeting the DOHS criteria requiring a minimum of 2,000 feet of horizontal separation.

- Optimize basin pumping and recharge to reduce local areas of high groundwater levels. One or both of the following could be varied: change the location and quantity of direct injection wells; redistribute pumping patterns using existing water supply wells.

- Improve accuracy of simulation baseline by introducing a statistically likely climatological regime to reproduce the natural fluctuations of atmospheric conditions and corresponding pumping rates, creating a more accurate representation of wet/average/drought periods.

- Refine the definition of the maximum acceptable groundwater level and clarify the impact of exceeding this level: allow the definition of maximum acceptable level to vary at different locations in the basin; determine what problems arise when the groundwater level exceeds the maximum acceptable level and identify how high groundwater levels could trigger these problems.

Additional Data and Analyses

To improve the accuracy of the predictions about the groundwater recharge alternatives and to produce the Engineers Report required by DOHS for a Groundwater Recharge Project, additional site-specific data will have to be collected and additional calculations made. Detailed recommendations are included in the preceding Local Scale Evaluation and Basinwide Scale Evaluation sections.

- Collect site-specific data at the target recharge sites, including depth to water, hydraulic parameters (transmissivity, storativity, and porosity), and groundwater quality.

- Field check nearby well locations, well status, well construction, and well use.

- Conduct more accurate, specific transient groundwater flow calculations at both the local and basinwide scale (over the project life; approximately 25 years) using, for instance, an enlarged version of the basinwide model with a particle-tracker attached.
- Explore alternative methods and strategies for reclaimed water recharge such as deep injection into the deepest sediments of the basin and smaller injection well fields throughout the forebay.
- Perform additional basinwide scale computer model simulations.

Summary

Regulatory and operational constraints as required by DOHS and SCVWD operations may limit the quantity of reclaimed water that can be recharged to the Santa Clara Valley subbasin. The regulatory constraints include a minimum depth to groundwater beneath surface recharge facilities, a minimum residence time for reclaimed water in the aquifer, and a minimum dilution (or maximum allowable fraction) of reclaimed water pumped from public supply wells. The operational constraints include: immediate demand; availability of local or import water to meet the currently envisioned 50 percent dilution before recharge criteria; and potentially, water quality.

The accuracy of the calculations made to date is approximately ±50 percent. The accuracy is limited by: lack of available site-specific data and lack of operational history (the injection alternatives) Collecting additional data and conducting additional calculations and numerical analyses will improve the accuracy of the current predictions.

Chapter 4
Demonstration Plant Influent Water Quality

Chapter 4

Demonstration Plant Influent Water Quality

The groundwater recharge demonstration plant will pilot test processes for use in the full-scale groundwater recharge treatment plant. The critical treatment parameters appear to be TOC, nitrate (total nitrogen), and total dissolved solids (TDS). This chapter addresses issues that affect the demonstration plant's influent water quality and these critical parameters, including the location at SJ/SC WPCP from which to draw influent, the disinfection process at SJ/SC WPCP, the need to denitrify SJ/SC WPCP effluent, and water quality data—both available and recommended. Therefore, this chapter discusses considerations for both the demonstration and full-scale plants.

The work completed under Task 2.7—Groundwater Recharge Reclamation Demonstration Plant Influent Quality can be summarized as follows:

- Select the most suitable location in the SJ/SC WPCP based on previous investigations, future facility planning, and engineering experience to draw influent for the demonstration plant.
- Evaluate potential changes to current SJ/SC WPCP disinfection process related to the quality and quantity of groundwater recharge reuse flow.
- Evaluate need for denitrification of the plant effluent regarding groundwater nondegradation levels for nitrate.
- Obtain and summarize the most current water quality data available for the selected demonstration plant influent.
- Identify potential additional influent water quality data required to properly identify groundwater recharge reclamation treatment requirements.
- Perform a limited amount of potential additional influent water quality sampling and analysis.

SJ/SC WPCP Location for Demonstration Plant Influent

There are several locations in SJ/SC WPCP from which influent for the groundwater recharge demonstration plant might be drawn. Figure 4-1 is a process flow scheme for SJ/SC WPCP. Table 4-1 lists four alternative locations and considers various impacts

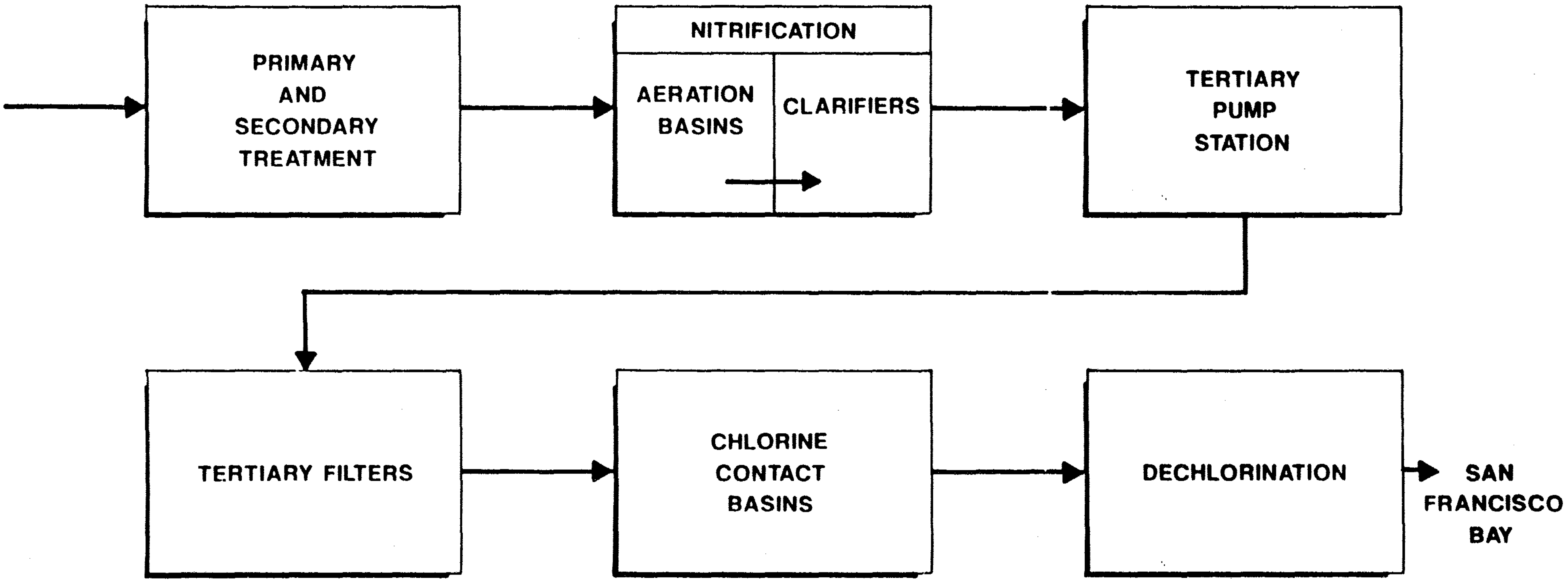

FIGURE 4-1
SJ/SC WPCP
PROCESS FLOW SCHEME

Table 4-1
Comparison of SJ/SC WPCP Locations from Which to Draw Groundwater Recharge Demonstration Plant Influent

Water Quality Impacts														
Alternative Locations	**Reduced TOC Concentrations**	**Increased TDS Concentrations**	**Reduced Nitrate Concentrations**	**Reduced THM and DBP Concentrations**	**Lower THMFP in Recharge Plant Influent**	**Lower Metals in Recharge Plant Influent**	**Lower Coliforms in Recharge Plant Influent**	**Reduced Filter O&M Cost at SJ/SC WPCP**	**Process Coordination Not Required**[a]	**Consistent with Nonpotable Pumping**[b]	**Space Available for Diversion Structure**	**Reduced Chlorination Costs at SJ/SC WPCP**	**Reduced Dechlorination Costs at SJ/SC WPCP**	**Reduced Sludge Handling and Disposal Costs at Recharge Plant**
Nitrification Effluent				NQ				1			2	2	2	
Filtered Effluent	2			NQ	NQ	1	1		3			2	2	1
Chlorinated Effluent	1	1	1		NQ	1	5		4		2		2	1
Dechlorinated Effluent		2	0		NQ	1	5		5	5	5			1

[a] No Coordination Required Between Diversion Pumping and SJ/SC Processes (Filter Application Rate, Chlorination Dose, Dechlorination Dose)

[b] Consistent with Pumping Strategy Proposed for SJ/SCVWD Nonpotable Reclamation Facility

Notes:

Scale:
1 - Minor relative impact
5 - Major relative impact
NQ - Degree of impact not quantified
Blank - No impact

each would have on the demonstration plant and SJ/SC WPCP. The four locations are listed below and then followed by a detailed discussion of each potential location.

- Nitrification effluent
- Filtered effluent
- Chlorinated effluent
- Dechlorinated effluent

The overriding constraint is concern for process reliability at SJ/SC WPCP because of strict NPDES discharge requirements. As a result, dechlorination effluent is the recommended location from which to take the demonstration plant influent since there are no potential impacts on SJ/SC WPCP discharge quality reliability. If any other location is selected from which to take the influent, there is a potential to negatively affect process reliability. Complicated flow measurement and chemical dosing requiring rapid response times could result in SJ/SC WPCP NPDES permit violations.

Nitrification Effluent Location

Clarified effluent from the 16 nitrification basins/clarifiers flows by gravity to the tertiary pump station. Five tertiary pumps lift the flow to allow gravity flow through the filters, chlorine contact tanks, and effluent channel. As there is no available space in the tertiary pump station, a new tap off the gravity pipe would be needed to bring flow to a new dedicated groundwater recharge reuse treatment plant influent pump station.

Plant operating data for the period November 1, 1990, through November 30, 1991, indicate the following removals through the filters and chlorine contact tanks:

- Biochemical Oxygen Demand (BOD)—56 percent reduction from 7.33 mg/l to 3.22 mg/l

- SS—81.6 percent reduction from 7.99 mg/l to 1.47 mg/l

- NH4-N—16.1 percent reduction from 1.93 mg/l to 1.62 mg/l

- NO3-N—No significant reduction

Data collected in 1989 for the City of San Jose In-Plant Metals Removal (Provision 5C) Report prepared by CH2M HILL indicate a slight reduction in metals through the filters and chlorine contact tanks.

Withdrawal of influent from nitrification offers the possibility of reduced THM and DBP concentrations as well as reduced filter Operation and Maintenance (O&M) cost at SJ/SC WPCP because the THM and DBP concentrations might be less at this location than those following final chlorination. However, according to Blue Ribbon Committee members Dr. Richard Bull and Mr. William Lauer, initial chlorination at the headworks of the plant probably forms the majority of the THM and DBP before final chlorination. Furthermore, the reduced O&M filter costs would be very low when compared with the increased control complexity.

Filtered Effluent Location

Filtered effluent flows from the filters through a channel to the chlorine contact tanks. Chlorine is added in the tertiary pump station wet well and again after the flow leaves the filters. Filtered effluent could be withdrawn from the channel upstream of the chlorine addition and pumped to the demonstration plant, but construction of this option would be very difficult.

The advantage of using filtered effluent is the possibility of a reduced THM and DBP concentration. Both nitrification effluent and filtered effluent may have less THM and DBP concentrations than the chlorinated plant effluent. The reduction after the filters would be slightly greater than that discussed for the nitrification location because some organic particles would be filtered out. However, as previously discussed, most THMs and DBPs are produced at the headworks, well ahead of this location. The disadvantages of this location include substantial modification of the plant process control system to ensure continuous disinfection and dechlorination.

Chlorinated Effluent Location

As discussed in the San Jose/Santa Clara Valley Water District Nonpotable Reclamation and Reuse Project Facility Plan technical memorandum titled "Comparison of Flow Diversion Before and After Dechlorination at the San Jose/Santa Clara Water Pollution Control Plant," diversion before dechlorination is not recommended. Diversion after dechlorination has a lower initial capital cost and present worth. It provides a cleaner interface between the SJ/SC WPCP operation and operation of the reclamation pumps and reclamation facility. It allows continued operation of the existing dechlorination system for the SJ/SC WPCP in the manual or automatic mode and is easier to construct.

The only advantage of using chlorinated effluent, as opposed to dechlorinated effluent, would be reduced dechlorination costs at SJ/SC WPCP.

Dechlorinated Effluent Location

Dechlorinated effluent could be removed from the effluent channel using the proposed diversion pump station planned for the nonpotable reclamation project.

The most significant advantage of using dechlorinated effluent is that this location has the least potential to interfere with WPCP operations, water quality, and reliability. In addition, the proposed diversion structure for the nonpotable pump station and diversion pipeline, scheduled for construction in 1994, has been sized to accommodate the entire groundwater recharge plant influent flow.

Summary

The dechlorinated effluent is the best overall location from which to take influent for the groundwater recharge project. All other locations will create an unacceptable risk of NPDES permit violation.

Modification of SJ/SC WPCP Disinfection Process

The SJ/SC WPCP currently uses chlorine gas to disinfect the entire plant flow. Chlorine is an effective disinfectant that can produce THMs when chlorine combines with certain organic compounds. Chloroform is the most prevalent THM compound formed when using free chlorine for disinfection. SJ/SC WPCP's NPDES permit does not currently have a limit for THMs. It is likely that when the permit is renewed it will include a limit for THMs because the California Enclosed Bays and Estuaries Plan (April 1991) sets limits of 480 mg/l for chloroform and 480 mg/l for halomethanes (bromoform, bromomethane [methyl bromide], chloromethane [methyl chloride], chlorodibromomethane, and bromodichloromethane) when discharging to waters that are not existing or to potential sources of drinking water.

DOHS standards currently require that drinking water must meet a total THM standard of 100 mg/l. This limit may drop to as low as 50 mg/l by 1995. Individual THM component concentrations may also be regulated by 1995.

Quarterly analyses performed December 1990 to December 1991 indicate that chloroform, bromodichloromethane, and chlorodibromomethane are the only THM compounds detected in SJ/SC WPCP effluent. The chloroform concentration averaged 6.5 mg/l, the chlorodibromomethane concentrations averaged 3.5 mg/l, and the bromoform was below the detection limit, for a total of 16 mg/l detected THMs. Therefore, it is likely that the SJ/SC WPCP effluent will meet the proposed 50 mg/l drinking water standards for THMs.

Ultraviolet radiation (UV) and ozone treatment are two methods of disinfecting wastewater that avoid producing THMs. Ozone is a more proven technology for disinfection, particularly for drinking water applications, but UV appears preferable because of the high capital and O&M cost of ozone.

The demonstration plant will consist of multiple treatment processes that may reduce THM concentrations. Reverse Osmosis will definitely remove THM precursors, lowering the THMFP, and may provide limited THM removals up to approximately 20 percent. Storing the potable effluent in recharge basins exposed to sunlight should lead to minor THM reductions because of UV degradation. Storing the reclaimed water in the groundwater basin and withdrawing it from wells also appears to provide some additional THM reduction. Based on recent studies by CH2M HILL of Aquifer Storage and Recovery (ASR) projects, when water containing THMs was injected into a groundwater basin and later pumped out, a THM concentration reduction was observed. The exact process responsible for this reduction has not been determined, although one theory is that the THMs are adsorbed onto clay particles. Because of lack of information on similar parameters, it is difficult to project THM removal rates that might be expected for the SJ/SC VWD groundwater recharge project, and so these reductions will not be included in THM compliance estimates.

Based upon THMs and groundwater reinjection, modifications to the existing disinfection process do not appear necessary to accommodate the groundwater recharge project. If water quality data during pilot testing should indicate that THMs and DBP levels in SJ/SC WPCP effluent are unacceptable, then costs should be included to provide the entire SJ/SC WPCP influent and effluent with an alternative disinfection system, such as ozone. At this time we do not anticipate that such action will be necessary.

SJ/SC WPCP Effluent Denitrification Evaluation

This section evaluates the need to denitrify SJ/SC WPCP effluent with respect to groundwater nondegradation levels for nitrate.

Local groundwater nitrate levels are approximately 3 mg/l (as N). Effluent data for SJ/SC WPCP indicate the following concentrations of nitrate expressed as nitrogen:

- Average Day—17 mg/l
- Maximum Month—23.3 mg/l
- Maximum Day—26.2 mg/l

Nitrate levels must be reduced before the reclaimed water can be discharged to recharge basins. This reduction can take place either at SJ/SC WPCP or at the full-scale groundwater recharge plant. Nitrate reduction at SJ/SC WPCP can be achieved by providing the appropriate conditions to allow bacteria to convert nitrate to nitrogen gas. Nitrate removal will take place in the RO and/or denitrifying filters in the groundwater recharge demonstration plant.

Nitrate reduction at SJ/SC WPCP could be accomplished in several different ways.

- Achieve nitrification and denitrification in separate steps. Provide an external carbon source such as methanol to the nitrification effluent. Construct additional reactors and clarifiers, similar to the existing nitrification basins and clarifiers, or fixed film reactors for the denitrification process. This represents a significant capital investment.

- Combine the nitrification and denitrification steps and use as a carbon source either:
  - Endogenous decay of the microorganisms
  - Carbon in the wastewater

  This method would not require constructing a third bank of reactors/ clarifiers, but would require modifications to sludge and process piping. The capital requirements of either combined system should be less than the separate system.

- Separate fixed film denitrification filters could be added at SJ/SC WPCP.

Partial in-plant biological denitrification reduced the total kjeldahl nitrogen (TKN) in a portion of the plant effluent to approximately 10 to 12 mg/l during 1990-1992 pilot work. However, complete in-plant denitrification of part of the SJ/SC WPCP flow has never been accomplished and would be difficult to achieve because of process control constraints, both in the nitrification process as well as in the downstream processes. Denitrification of the entire SJ/SC WPCP flow is not economically justifiable given that nitrates are not a concern in discharging to the South Bay. Denitrification of the groundwater recharge flow at the reclamation plant using separate reactors or denitrification filters is the recommended option.

Nitrate reduction at the groundwater recharge demonstration plant could be accomplished other ways but would most likely use a combination of RO and fixed film dentrification filters. The demonstration plant is expected to include RO, which is assumed to remove 65 percent of the nitrate. If the potable effluent must meet the 10 mg/l nitrate Drinking Water Standard, then RO alone will reduce the nitrate concentration to acceptable levels. If the potable effluent must meet the 3 mg/l concentration of the existing groundwater, then additional denitrification using denitrifying filters will be required.

Water Quality Data

This section summarizes the water quality data that have been provided by the SJ/SC WPCP. Effluent from the SJ/SC WPCP will be used as influent to the demonstration plant. First, the type of data that have been provided is listed. Next, implications that particular data will have on the groundwater recharge treatment plant are discussed. Finally, additional data that will be required before proceeding with subsequent phases of the project are presented.

Existing Data

SJ/SC WPCP provided copies of monthly discharge reports that are sent to RWQCB. The reports included the following periods:

- 1982—a wet year
- 1984—a normal precipitation year
- 1991—a recent dry year

The following categories of data were monitored:

- General data
- Bacteriological data
- Inorganic data
- Organic compounds

Tables 4-2, 4-3, 4-4, and 4-5 summarize available data for SJ/SC WPCP effluent. Table 4-2 lists types of data that are monitored daily and are included in the general data and bacteriological data categories. Drinking water standards are included where applicable.

The inorganic contaminants category includes the compounds listed in Table 4-3. These contaminants are monitored weekly unless otherwise indicated in the table. U.S. Drinking Water Standards are included where applicable.

The organic compounds category includes pesticides, polychlorinated biphenols (PCBs), volatile organic compounds and semivolitile organic compounds. Table 4-4 lists the organic compounds tested during the five quarterly analyses (12/90 to 12/91). Asterisks indicate compounds that were only tested for once. Only those chemicals that were detected or for which a Drinking Water Standard has been set are included in the upper portion of the table.

Total organic carbon has been regularly monitored by SJ/SC WPCP for more than a decade, although it is not included in the monthly RWQCB reports. During 1991, the SJ/SC WPCP effluent averaged 11 mg/l TOC, with a maximum monthly average of 16 mg/l.

TOC Content

In considering standards for treatment plant effluent used for groundwater recharge, it has been suggested that the composition of TOC in import or surface water might reflect a more natural organic content, while TOC in SJ/SC WPCP effluent might reflect a more manmade, industrial content, which might pose a greater risk to public health when injected into the groundwater. The concern is to evaluate the risk to the groundwater by injecting reclaimed water with unknown or hazardous TOC content.

Table 4-2
Monitored General/Bacteriological Data

Parameter	Unit	SJ/SC WPCP Effluent 1991 Annual Average	SJ/SC WPCP Effluent 1991 Maximun Month	Drinking Water Standards
Flow	*mgd*	100	105	
Biochemical Oxygen Demand (BOD)	*mg/l*	3	4	
Suspended Solids (SS)	*mg/l*	1.6	2.0	
Grease and Oil	*mg/l*	<1.5	<2.3	
Settleable Solids	*mg/l-hr*	0.0	0.0	
pH	--	6.8	7.0	6.5 - 8.5[a]
Temperature	*°C*	17	25	
Dissolved Oxygen	*mg/l*	6.5	8.0	
Turbidity	*NTU*	1.0	1.0	1.0[b]
Apparent Color	*color units*	17.0	20.0	15.0[a]
Floating and Suspended Matter	--	None	None	
Odors	--	None	None	
TOC	*mg/l*	11	16	
Total Coliforms	*MPN*	2.2	2.8	1.0[b]

[a] U.S. Secondary Drinking Water Standard
[b] U.S. Primary Drinking Water Standard; Turbidity scheduled to decrease to 0.5 NTU in June 1993.

Note:
Monitored Daily, Reported in RWQCB monthly discharge reports

Table 4-3
Monitored Inorganic Contaminants

Parameter	SJ/SC WPCP Effluent 1991 Annual Mean	SJ/SC WPCP Effluent 1991 Maximum Month	Drinking Water Standards
Arsenic	<2	<5	50[a]
Cadmium	<0.5	<0.5	10[a]
Cyanide	14	38	50[a]
Chromium	1.1	1.8	50[a]
Copper	7	9	1,300[b]
Lead	<1	2	15[a]
Mercury	<0.2	2	2[b]
Nickel	13	29	--
Ammonia Nitrogen (Daily)[c]	1.7	2.0	--
Nitrate Nitrogen (Daily)[c]	17.0	23.3	10[a]
Organic Nitrogen (Daily)[c]	0.5	0.7	--
Total Phosphate (Daily)[c]	13.5	18.9	--
Selenium	<0.8	1.7	50[a]
Silver	3	4	50[a]
Zinc	53	76	5,000[b]

[a] U.S. Primary Drinking Water Standard
[b] U.S. Secondary Drinking Water Standard
[c] Annual Average, mg/l

Notes:
Monitored weekly unless noted otherwise. *Reported in RWQCB monthly discharge reports*
μg/l except as noted

Table 4-4
Monitored Organic Compounds
Detectable Concentrations or Drinking Water Standard

Parameter	SJ/SC WPCP Effluent	Drinking Water Standard[a]
Pesticides and PCB's		
Endrin	ND	0.2
Methoxychlor	ND	100
Toxaphene	ND	5
Arochlor (PDB) - 1260	9.4(1)	
Lindane	ND	0.4
Volatile Organic Compounds		
Chloromethane	1(1)	
Vinyl Chloride	ND	2
1,1 Dichloroethene	ND	7
Acetone	9(1)	
Chloroform[b]	6.5(4)	[b]
1,1,1-Trichloroethane	ND	200
Carbon Tetrachloride	ND	5
Benzene	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
Bromodichloromethane[b]	6(2)	[b]
Chlorodibromomethane[b]	3.5(2)	[b]
Semivolatile Organic Compounds		
1,4-Dichlorobenzene	ND	75
Napthalene	1.5(1)	
Butyl Benzyl Phthalate	11(1)	
Bis(2-ethylhexyl)phthalate	33(1)	

[a] U.S. Primary Drinking Water Standard.

[b] Trihalomethane Compound with Drinking Water Standard of 100 µg/l Total THMs.

Notes:

Monitored quarterly unless noted otherwise. Reported in RWQCB monthly discharge reports.

Test conducted 12/90, 3/91, 6/91, 9/91, and 12/91. Concentrations given in micrograms per liter.

(#-) Compound detected in # out of five tests. Concentration listed is average value of tests with detectable amounts e.g., 6.5(4) means compound was detected in four out of five tests, and concentrations averaged 6.5 µg/l.

[ND] Not Detected in each of five tests (generally <1 µg/l).

Table 4-5
Monitored Organic Compounds
Nondetectable Concentrations

Pesticides and PCB's		
alpha-BHC	Chlordane	Chloripyrifos[a]
beta-BHC	Arochlor (PCB)-1016	Coumaphos[a]
gamma-BHC	Arochlor (PCB)-1221	Azinphos methyl
delta-BHC	Arochlor (PCB)-1232	Phorate[a]
Heptachlor	Arochlor (PCB)-1242	Prothiofos[a]
Aldrin	Arochlor (PCB)-1248	Ronnel[a]
Heptachlor epoxide	Arochlor (PCB)-1254	Tetrachlorvinphos[a]
Endosulfan I	Demeton-O&S	Trichloronate[a]
Dieldrin	Diazinon	Dichlorvos[a]
4,4'-DDE	Disulfoton	Ethoprop[a]
Endosulfan II	Methyl parathion	Fensulfothion[a]
4,4'-DDD	Malathion	Fenthion[a]
Endosulfan Sulfate	Ethyl parathion	Merphos[a]
4,4'-DDT	Ethion[a]	Mevinphos[a]
Endrin aldehyde	Total Identifiable Chlorinated Hydrocarbons	Naled[a]
Endrin ketone	Bolstar[a]	
Volatile Organic Compounds		
Bromomethane	trans-1,2- Dichloroethene	Tetrachloroethene
Chloroethane	1,1-Dichloroethane	Chlorobenzene
Trichloroflouromethane	1,2-Dichloropropane	Ethylbenzene
Trichlorotrifluoroethane	2-Chloroethyl-vinyl ether	Bromoform[b]
Styrene[a]	cis-1,3-Dichloropropene	1,1,2,2-Tetrachloroethane
Carbon Disulfide[a]	Toluene	1,3-Dichlorobenzene
4-Methyl-2-pentanone[a]	trans-1,3-Dichloropropene	1,4-Dichorobenzene 1,2-Dichlorobenzene
Methylene chloride	1,1,2-Trichloroethane	Xylenes
Semivolatile Organic Compounds		
Benzidine	2-Chloronaphthalene	Pyrene
Phenol	Dimethyl phthalate	3,3'-Dichlorobenzidine
Bis(2-chloroethyl)ether	Acenaphthylene	Benzo(a)anthracene
2-Chlorphenol	Acenaphthene	Bis(2-ethylhexyl)phthalate
1,3-Dichlorobenzene	2,4-Dinitrophenol	Chrysene
1,2-Dichlorobenzene	4-Nitrophenol	Aniline[a]
Bis(2-chloroisopropyl)ether	2,4-Dinitrotoluene	Azobenzene[a]
N-Nitrosodi-n-propylamine	2,6-Dinitrotoluene	N-Nitrosdimethylamine
Hexachloroethane	Diethyl phthalate	Benzyl Alcohol[a]

Table 4-5
Monitored Organic Compounds
Nondetectable Concentrations

Pesticides and PCB's

Semivolatile Organic Compounds (continued)

- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Bis(2-chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 4-Chlorophenylphenylether
- Fluorene
- 2-Methyl-4,6-Dinotrophenol
- N-Nitrosodiphenylamine
- 4-Bromophenylphenylether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-Butyl phthalate
- Flouranthene
- 2,4,5-Trichlorophenol[a]
- 2-Nitroaniline[a]
- 3-Nitroaniline[a]
- Di-n-octyl phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenzo(a,h)anthracene
- Benzo(g,h,i)perylene

[a] *Compounds tested for one time only.*

[b] *Trihalomethane Compound.*

Notes:

Monitored quarterly unless noted otherwise.

Reported in RWQCB monthly discharge reports. Test conducted 12/90, 3/91, 6,91, 9/91, and 12/91.

Concentrations given in micrograms per liter. Concentrations were below the detection limit (generally <1 μg/l.) These organic compounds not included in Drinking Water Standards.

Dr. Richard Bull, a Blue Ribbon Committee member, has stated that, in his experience, no more than 5 percent of the TOC components in domestic waters and wastewaters are usually identifiable. This point is substantiated by the SJ/SC WPCP effluent data, in which average and maximum TOC was 11 and 16 mg/l in 1991, while testing during this same period identified only .081 mg/l specific organic constituents, or 0.7 percent as reported in Table 4-4. If an additional 1.5 mg/l grease and oil in the effluent is assumed to be 100 percent TOC, it would only identify another 14 percent of the total organic components. Similarly, if all 124 of the undetected organics constituents listed in Tables 4-4 and 4-5 are assumed to be present at the detection limit of 1 mg/l, then an additional 0.124 mg/l of TOC would have been identified, or an additional 1.1 percent of the total average TOC. It is usually assumed that the remaining unidentified TOC is composed of humic and fulvic acids, decomposing plant or animal matter, typically of large molecular weight.

The recommended approach to resolving the TOC content issue is to analyze various samples during pilot testing for organics using a GC mass spectrometer (GCMS) and compare results. The recommended various samples include:

- Groundwater (both chlorinated and unchlorinated)
- Import water
- Reclaimed water
- SJ/SC WPCP effluent/demonstration plant influent
- Treated water from SCVWD Water Treatment Plants (WTPs)
- Hetch Hetchy raw water

A key element in resolving TOC content will be "challenge testing," during the pilot studies, where the demonstration plant influent will be spiked, with high concentrations of various manmade organic chemicals, and then the reclaimed water effluent will be tested for removal efficiency. The demonstration plant influent and effluent GCMs graphs will be compared to see whether similar spikes exist, indicating spiked chemical breakthrough. William Lauer, a Blue Ribbon Committee member, said that similar challenge testing at the Denver Direct Potable Reuse Demonstration Plant indicated a highly-successful removals efficiency, which led to an increased confidence in the reclaimed water processes.

It has been noted that TOC quantity alone is not the issue, but rather the quantities and health effects of specific organic compounds, identified and unidentified, known and unknown. In the case of known chemicals, the organic constituents may need to be reduced well below existing limits on the basis that the allowable concentration limits may be reduced further at some future time. Reducing overall TOC quantities will hopefully reduce the quantities of compounds of concern. In addition, there is also the possibility that other organic chemicals may be newly found to pose health risks.

Dr. Richard Bull, another member of the Blue Ribbon Committee, recommended that a limited program be implemented to identify what organics are used in the community and thus might be observed in the wastewaer and reclaimed water.

Separate processes that each remove organics will act as multiple barriers to decrease the risk of process breakdowns and increase the comfort level. Processes that remove organics include high pH, lime, RO, and GAC. Risk from unknowns may also be reduced by increasing process redundancies, especially GAC. Increasing the percent of the treatment plant flow that passes through GAC may be desirable to decrease the risk from unknowns.

Implications of Existing Data

The data presented in Tables 4-2, 4-3, and 4-4 are provided in the monthly report to RWQCB and focus on influent and final effluent quality. These data demonstrate that the overall plant percent removal and effluent quality requirements are achieved.

Existing data indicate that SJ/SC WPCP can be treated to meet the applicable recharge water quality standards. Parameters that need to be quantified during subsequent testing are identified in the following section.

Additional Data Required

The Denver Water Department operates a Direct Potable Reuse Demonstration Plant (DPRDP) that uses unchlorinated secondary effluent for the potable influent. The data available for SJ/SC WPCP were compared with data from the Denver DPRDP to determine applicable parameters that could be sampled before or during pilot testing.

Table 4-6 summarizes some parameters that have been monitored at the Denver DPRDP but not at SJ/SC WPCP. We recommend that tests be run for all parameters listed in Table 4-6, on either and/or both SJ/SC WPCP effluent and groundwater recharge treatment plant effluent. We recommend that SJ/SC WPCP effluent be monitored for total alkalinity, hardness, TDS, and specific conductance before the demonstration facility predesign. Bench-scale testing should also be performed over a 1-week period before setting chemical doses and process design criteria.

The other general parameters listed in Table 4-6 should be monitored during pilot testing. Radiological parameters should be determined by conducting quarterly Full Range Safe Drinking Water Act parameter tests during pilot testing to establish a baseline. Microbiological parameters should be monitored during pilot testing. Inorganic parameters should be monitored during pilot testing by conducting atomic absorption identification tests per EPA standards. During the pilot study period we recommend one GC mass spectrometer run/test per quarter be performed to report any of the organic compounds in Table 4-6 that are at detectable levels. In addition to testing the final plant effluent, quarterly testing may later be recommended for nitrification effluent and filtered effluent, depending on the selected source of groundwater recharge plant influent. Costs to perform these various tests will be estimated in the next phase of work.

Table 4-6
Additional Recommended Water Quality Testing

General[a]	
• Total Alkalinity • Hardness • TDS	• Specific Conductance • Asbestos—million fibers/l • Methylene blue active substances
Radiological[b]	
• Gross Alpha—pCi/l • Gross Beta—pCi/l	• Radium 228—pCi/l • Radium 226—pCi/l
Microbiological[b]	
• m-HPC—count/ml • Fecal strep—count/ml • Fecal coliform—count/100ml • Coliphage B—count/100ml • Coliphage C—count/100ml	• Giardia—cysts/l • Endamoeba coli—cysts/l • Algae—count/l • Enteric virus • Entamoeba histolytica—cysts/l • Cryptosporidium—cysts/l
Inorganic[b]	
• Antimony • Barium • Boron • Bromide • Calcium • Chloride • Ionide • Iron • Lithium	• Magnesium • Manganese • Molybdenum • Potassium • Silica[b] • Sodium • Strontium • Sulfate • Titanium • Vanadium
Organic Compounds[b]	
• Bromobenzene • 1,2,3-Trichloropropane • 1,1,2,2-Tetrachloroethane • n-Propylbenzene • 2-Chlorotoluene • 4-Chlorotoluene • 1,3,5-Trimethylbenzene • tert-Butylbenzene • 1,2,4-Trimethylbenzene • sec-Butylbenzene • p-Isopropyltoluene(p-Cymene) • n-Butylbenzene • DBCP (1,2-Dibromo-3-chloropropane) • 1,2,3-Trichlorobenzene • trans-Decalin • cis-Decalin • 2,4-D • 2,4,5-TP • Trichloroacetonitrile[c] • Dichloroacetonitrile[c] • 1,1-Dichloropropanone • Chloropicrin[c]	• Bromoacetonitrile[c] • 1,1,1-Trichloropropanone • Dibromoacetonitrile • Trihalomethanes[c] • Cyanogen chloride[c] • Monochloroacetic acid[c] • Monobromoacetic acid[c] • Dichloroacetic acid[c] • Trichloroacetic acid[c] • Dibromoacetic acid[c] • 2,2-Dichloropropane • cis-1,2-Dichlorpropane • Bromochloromethane[c] • 1,1-Dichloropropene • Dibromomethane • cis-1,3-Dichloropropene • 1,3-Dichloropropane • EDB(ethylene Dibromide) • 1,1,1,2-Tetrachloroethane • o,m,p-Xylene • 1-Methylethylbenzene (cumene)

[a] *Run tests on SJ/SC WPCP effluent before groundwater recharge demonstration plant predesign.*
[b] *Run on groundwater recharge demonstration plant influent and effluent during pilot testing.*
[c] *Disinfection by-products.*

Recommendations

We recommend that SJ/SC WPCP dechlorinated effluent be used for the influent to the groundwater recharge demonstration plant. If denitrification is required to lower nitrate levels below those achievable by RO alone, we recommend that denitrifying filters be included at the groundwater recharge demonstration plant. We recommend that additional data be collected as detailed in the Water Quality Data section and summarized in Table 4-6.

Blue Ribbon Committee Comments

Both Dr. Bull and Mr. Lauer indicated that the SJ/SC WPCP effluent data did not show any surprises. Several additional water quality testing parameters during pilot testing were recommended and have been included in Table 4-6.

Dr. Bull and Mr. Lauer agreed that if there are significant THMs formed in the SJ/SC WPCP process, then they are likely formed in the prechlorination step rather than the final disinfection.

Dr. Bull and Mr. Lauer concurred with organic chemical testing program to measure and compare the various product streams (influent, effluent, import water) and conduct "challenge" testing wherein high concentrations of certain compounds are added to the influent to observe treatment performance.

Dr. Bull suggested changes to SJ/SC WPCP pretreatment program to try and identify which organics are used and thus which organics should be looked for in the reclaimed water. Mr. Lauer commented that a program of this sort was tried as part of the Denver project, but that it was very time consuming and did not account for organic chemical products formed during the pretreatment industries process. Given the relative lack of benefit gained from the pretreatment program during the Denver Reuse project, Mr. Lauer suggested that major pretreatment program changes may not be warranted but rather that only a limited program be considered.

Chapter 5
Regulatory Treatment Requirements

Section 5
Regulatory Treatment Requirements

As a part of the City of San Jose's investigation into the possibility of indirect potable reuse either through groundwater recharge via surface spreading or direct injection, it is essential to balance the water quality concerns from the various sources of recharge water and the extracted water used in the domestic system. The water currently used for recharge is either local surface water resulting from precipitation in the Santa Clara Valley watershed or imported water from the Sacramento/San Joaquin Delta. The water that would be used to augment that recharge would be treated effluent from the SJ/SC WPCP. From an initial analysis, the three water quality constituents of concern regarding the potential for recharge using treated effluent are Nitrate (or total Nitrogen expressed in mg/l), TDS,mg/l, and TOC, mg/l. There is a primary health-based standard for nitrate at 10 mg/l as N; a secondary aesthetic based standard for TDS at 500 mg/l; and a general concern for TOC based upon the uncertainty related to organic contamination.

In addition, there are a variety of regulatory constraints identified below, and a discussion as to which constituent and regulatory constraint may be controlling in each case.

Controlling Criteria and Standards

State and Federal Drinking Water Standards

The state and federal Drinking Water Standards, summarized in Table 5-1, established under the authority in the respective Safe Drinking Water Acts, promulgate MCLs for various constituents in drinking water. Recently, EPA was mandated by Congress to add MCLs for 25 new organic compounds to the Drinking Water Standards every three years. The purpose of these MCLs is to adequately protect the public health, and provide water that is aesthetically acceptable to the consumers. The impact of these standards on a groundwater recharge project relates to the fact that the drinking water always has to meet the MCLs, and anything done during the recharge operation to place the compliance with the standards at risk is unacceptable. Various contaminants present in the effluent of the San Jose/Santa Clara Water Pollution Control Plant do not meet the drinking water standards and will have to be addressed in the treatment requirements. Most notable of these are nitrate and coliform bacteria.

State "Action Levels"

In addition to the state and federal "enforceable" drinking water standards, the State of California also establishes informal action levels for those compounds that have not had

Table 5-1
Water Quality Information

	SJ/SC WPCP Effluent[a]		DOHS Groundwater Recharge[b]	EPA Drinking Water Standard[c]	SC Valley Groundwater[d]	Import Water
	Average	Maximum				
TDS (mg/l)	870		500	500	350	321
Nitrate (as N)(mg/l)	17.0	23.3	10	10	3.4	<1
Total Nitrogen as N (mg/l)	19.3	25.9	--	--	3.4	<1
Arsenic	<2.0	<5	50	50	--	2
Cadmium	<0.5	<0.5	10	10	1 to 2	--
Chromium, Total	1.1	1.8	50	50	<1 to 5	--
Copper	7	9	1,000	1,300	<10 to 50	<5
Lead	<1	<2	50	15	<10 to 30	<5
Mercury	<0.2	0.3	2	2	--	--
Nickel	13	17	---	---	<10	--
Silver	3	4	50	50	<5	--
Zinc	53	76	5,000	5,000	<100	--
Total Coliform (MPN)	2.5	8.0	---	1	--	--
Turbidity (NTU)	1	2	---	1[f]	--	--
TOC (mg/l)	11	16	20/5/6/2[e]	---	0.2 to 1.5	3 to 4

[a] 1991 data. Provided by the SJ/SC WPCP.

[b] Proposed standards, expected to be finalized in 1992.

[c] EPA Primary and Secondary Drinking Water Standards. All Standards listed are primary standards (indicating a relationship between concentration and public health protection) except copper, zinc, and TDS, which are secondary standards (taste and odor related), pH, which is based upon aesthetic criteria, and cyanide, which is health based.

[d] Groundwater Quality Monitoring Program for the Santa Clara Valley Groundwater Basin. Santa Clara Valley Water District, July 1986.

[e] 20% Dilution: 20 mg/l surface recharge, 5 mg/l direct injection.
50% Dilution: 6 mg/l surface recharge, 2 mg/l direct injection.

[f] Scheduled to decrease to 0.5 NTU in June 1993.

Note: μg/l except as noted.

formal MCLs established because of recent discovery or lack of widespread occurrence. Each of the current 28 action levels represent agricultural or industrial chemicals. A complete listing of the MCLs and action levels follows this chapter.

State Groundwater Recharge Regulations

The State of California, Department of Health Services, Office of Drinking Water has a regulation in place regarding groundwater recharge with reclaimed wastewater (Ref. 5-1), and has issued draft changes to those regulations (March 2, 1992) to make the requirements more specific. The draft criteria for specific concentrations are also summarized in Table 5-1. In order to address other aspects of the draft regulations, consideration will have to be given to the depth to groundwater beneath the recharge facilities, the distance to the nearest well(s) from the recharge facilities, the time of travel between the recharge facilities and the well(s), and the percent of reclaimed water in the well water. These criteria may dictate the treatment requirements and the location of recharge facilities to be used in the indirect spreading or injection program.

State Nondegradation Policy

SWRCB adopted Resolution 68-16 in 1968 entitled, Statement of Policy with Respect to Maintaining High Quality of Waters in California. Strict interpretation of this policy could require that the recharge water be treated to the extent that the use would not "degrade" the existing supply without defining what constitutes degradation. An example of this is the comparison of the water quality in the groundwater with the water used for recharge under the existing operation. The concentration of TOC in the groundwater in the Santa Clara Valley Subbasin ranges from 0.2 to 1.5 mg/l (source: Santa Clara Valley Water District data from 1984), but the TOC in the imported water from the Sacramento/San Joaquin Delta varies between one and 5 mg/l. This recharge operation has been in place for a considerable period of time, but the quality of the groundwater, as measured by TOC, has not "degraded." Existing groundwater concentrations are presented in Table 5-1.

The original decision to consider RO treatment of the reclaimed water used for groundwater recharge was based upon the fact that the TDS concentration in the groundwater is approximately 300 to 400 mg/l less than the TDS in the wastewater treatment plant effluent. The three water quality constituents that will have to be addressed in relation to this policy are TDS, TOC, and nitrogen.

State "Recommended Public Health Levels"

The passage of the California Safe Drinking Water Act Amendments of 1989 included the provision that the State DOHS must establish recommended public health levels (RPHLs) for contaminants in drinking water, and those RPHLs must be set at a level at which..."no known or anticipated adverse effects on health will occur." The state has published a draft list of RPHLs and these compounds will have to be considered in the monitoring program established for the groundwater recharge program. The SJ WPCP effluent has not been tested for all RPHC contaminants, although extensive organic testing has been done, as required by the NPDES permit and as summarized in Chapter 4. None of the draft RPHLs appear to be a problem at this time, but monitoring and treatment requirements should be designed to address potential problems that may occur. The existing water utilities will have to monitor and report on any compounds that are at variance with the standards.

Constituent and Criteria Specific Requirements

Nitrogen

Examination of the data from the SJ/SC WPCP shows that the total average nitrogen in the discharge for 1991 was 19.3 mg/l (17.1 Nitrate, 1.7 Ammonia, and 0.5 Organic Nitrogen). The nitrogen in the groundwater averages 3.4 mg/l in the Santa Clara Valley subbasin (source: SCVWD). The water purveyors primarily use the Santa Clara Valley subbasin as their groundwater source. This average data exclude those samples that exceed the drinking water standard MCL of 10 mg/l nitrate as nitrogen. Data from the State Department of Water Resources indicate that the imported water generally has less than 1 mg/l nitrogen and that the local surface water is of similar quality.

The choice that must be made is whether to treat the reclaimed wastewater to a level of total nitrogen that exists in the groundwater, referred to as the groundwater nondegradation standard, or to allow for blending with the other recharge water, referred to as the composite standard. Table 5-2 summarizes these treatment standards. If we assume that blending is a possibility, our target treatment level, assuming 50 percent blend, would be approximately 5.8 mg/l as nitrogen. If the reclaimed wastewater percentage is higher, the effluent will be higher in total nitrogen and vice versa. The use of total nitrogen as a criteria, rather than nitrate, is more conservative, but recognizes the fact that in the groundwater all nitrogen will be in the nitrate form. Using the average data for nitrogen as shown above, the removal percentages of 65 percent for nitrate, 85 percent for ammonia, and 75 percent for organic nitrogen, the effluent from the RO treatment is expected to average between 6 and 6.5 mg/l as N, but may be lower if some of the nitrogen is removed in the pretreatment steps to the RO unit.

The groundwater recharge regulation draft states that..."The monthly average of the total nitrogen concentration of the reclaimed water shall not exceed 10 mg/l as N unless the project sponsor can demonstrate that the total nitrogen standard of 10 mg/l as N can be consistently met before reaching the saturated zone directly beneath the recharge basin." In this case they do not consider the State Nondegradation Policy to be controlling and a determination should be made as to which criteria should be employed. Also, nitrate levels are high in some parts of the percolation basins.

Table 5-2
Treatment Standards

Standard	Reclaimed Water Concentration			Based On
	TDS (mg/l)	NO_3 as N (mg/l)	TOC (mg/l)	
Groundwater nondegradation	350	3.4	1.0	Limited groundwater data
Composite 20 percent dilution[a]; surface recharge or direct injection	350	-	-	Current average groundwater concentrations
	-	10	-	Import and local surface water currently used in percolation ponds. N = 0-1 mg/l; DOHS draft Groundwater Recharge Regulations allow 10 mg/l or less. Blend to 3.4 mg/l or less.
	-	-	2.5	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 20/5 mg/l.
Composite 50 percent dilution[b]; surface recharge	350		-	Current average groundwater concentrations
	--	5.8	--	Import and local surface water currently used in percolation ponds, N = 0-1 mg/l. Blend to 3.4 mg/l or less.
	--	--	2.5	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 6 mg/l.
Composite 50 percent dilution[b]; direct injection	350	--	--	Current average groundwater concentrations
	--	5.8	--	Import and local surface water currently used in percolation ponds N = 0-1 mg/l. Blend to 3.4 mg/l.
	--	--	1.6	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 2 mg/l.

[a] Twenty percent reclaimed water is combined with 80 percent import water/surface water/treated water before surface or injection well recharge.

[b] Fifty percent reclaimed water is combined with 50 percent import water/surface water/treated water before surface or injection well recharge.

Recharging with reclaimed water that meets the 10 mg/l as N DOHS requirement will provide no dilution of the higher nitrate levels in the groundwater that the current operation accomplishes.

Total Dissolved Solids

The original decision to use RO was based upon the Nondegradation Policy and the recognition that the ambient groundwater TDS is lower than the SJ/SC WPCP effluent TDS. The ambient TDS in the Santa Clara Valley subbasin averages 526 mg/l, higher than the State Secondary Drinking Water Standard recommended at 500 mg/l; the TDS in the Coyote-Llagas subbasin averages 387 mg/l. The SJ/SC WPCP averages 870 mg/l, and we may assume that this concentration will be reduced by 90 percent using RO to less than 100 mg/l. In this case the TDS concentrations will be reduced in the total system.

Total Organic Carbon

The TOC in the ambient groundwater averages between 0.7 and 1.1 mg/l in the two subbasins, with the Santa Clara Valley subbasin ranging from 0.2 to 1.5 mg/l. Effluent from the RO treatment is expected to be 1.6 mg/l or less and will dilute the TOC present in the local and imported surface water. Depending upon the season and the local conditions in the Sacramento/San Joaquin Delta, the TOC in the imported water can be as high as 5 mg/l.

Vertical Distance to Groundwater

Based upon data obtained from the Santa Clara Valley Water District the historical minimum depth to groundwater in the vicinity of the existing percolation ponds is 10 feet or less in some locations. For the purposes of the draft groundwater recharge regulations this does not meet the criteria for Category I, surface spreading. This criterion may be a controlling factor in determining either treatment, recharge location, or recharge operations when high groundwater conditions exist.

This criterion would not be a controlling factor for surface recharge if the regulatory agencies accepted the approach that the surface recharge facilities be considered very shallow direct injection wells. Because direct injection is into the groundwater basin, there is no vertical distance to groundwater requirement in the DOSH regulations. Instead, health concerns are mitigated by higher water quality requirements. If the reclaimed water were to be treated to meet the groundwater nondegradation standard, then the reclaimed water will also meet the DOHS draft water quality standards for direct injection. Thus, this regulatory constraint may not constrain groundwater recharge. Operational constraints because high groundwater are discussed in Chapter 3.

Horizontal Distance to the Nearest Well

Based upon data obtained from the SCVWD, there are production wells located within 1,000 feet of the recharge ponds. This criterion will be a controlling factor in determining either recharge location or abandonment of adjacent water supply wells.

Residence Time in the Groundwater

Based upon data developed in the local models hydraulic analysis tasks, the travel time from the recharge ponds to the nearest wells will probably be less than 6 months depending on the specific well location and hydrogeology, exceeding that allowed in the draft criteria for groundwater recharge. This factor will also control either the location for the recharge or the treatment of adjacent water supply wells.

Percent Reclaimed Water in the Extracted Domestic Supply

The current "maximum case assumption" is that the reclaimed water will be blended 50/50 with dilution water in the recharge basins. The amount of reclaimed water in the nearest well cannot be determined at this time, but it will be less than 50 percent because of natural dilution occurring in the aquifer. The draft reclamation criteria indicate that for 50 percent reclaimed wastewater the TOC cannot exceed 6 mg/l in the reclaimed water. The estimated TOC in the reclaimed water available for recharge has been estimated at 1 mg/l or less TOC; this will reduce the total amount of TOC by diluting the other surface water TOC.

Unresolved Issues and Data Needs

Department of Health Services Guidelines

The absence of final promulgated recharge guidelines from the DOHS will be an issue until they are formally established as regulations.

Nondegradation Policy Interpretation

The major unknown in this project involves how the Non-Degradation Policy will be interpreted for nitrogen. The expected nitrogen content in the reclamation plant effluent will be from 6 to 6.5 mg/l as N, exceeding the average nitrogen in the ambient groundwater. If credit for 50/50 or greater blending is taken into account, the recharge water will have total nitrogen of approximately 3 mg/l or less. More data on the nitrogen levels in the water currently used for recharge are needed to correctly assess the impact of the blending.

Waste Residual Disposal Issues

Waste residual issues are addressed in Chapter 7, Treatment Residuals.

Impact of Forthcoming Drinking Water Standards

The water utilities in the Santa Clara Valley will have to address the potential impact of EPA regulations on radon (final rule expected mid-1993), groundwater disinfection (draft rule expected mid-1993), and on the current lead and copper rule. The proposed groundwater recharge using blended reclaimed water will not have an impact on any of those three rules and the water utilities will be required to developed plans for dealing with the rules independent of the recharge operation. Implementing the groundwater disinfection rule could, independent of this project, cause the water utilities to produce THM. The current drinking water standard for THM is 100 parts per billion (ppb) in drinking water. This level is expected to be reduced to 50 ppb or less in the revision of the Disinfection By-Product Regulations scheduled for draft proposal in mid-1993. The planned recharge operation is not expected to have an impact on the groundwater or the THM regulations. There will be some low level of THM in the treated wastewater that will be discharged to the basins, but that level will be reduced via blending in the basin, degradation via ultraviolet light, and attenuation in the groundwater. Experience on other groundwater recharge projects has shown that water with THM injected directly into a potable aquifer showed some THM reduction when extracted several months later. The data from the recharge project in the Whittier Narrows area of Los Angeles County confirm this finding in their wells.

Existing Santa Clara Valley Groundwater Quality Data

There is a need for additional data on the water quality currently being used for recharge in the Santa Clara Valley so that we may assess the potential for improving the quality via blending. There are water quality data available from either the State Department of Health Services or the individual water purveyors to allow us to assess the current water quality near the basins. Data are probably not available from the water utilities for TOC, because that is typically not something a domestic utility would include in a sample and monitoring program.

Blue Ribbon Committee Comments

Mr. Lauer suggested that a diverse advisory panel be formed to act as a sounding board for the project as it progresses, similar to one formed in Denver for the Denver Potable Water Reuse Demonstration Project. The advisory panel might be comprised of lawyers, environmentalists, consumers, engineers, and all other interested groups. Mr. Bull also thought that this would be helpful for successful project development.

MCLs and Action Levels Listing

e of California Department of Health Services

emorandum

: To All Concerned

Date : October 24, 1990

Subject: Summary of California Drinking Water Standards

n : Office of Drinking Water
2151 Berkeley Way, Rm. 113
Berkeley, CA 94704

Attached is a copy of the most current summary of Maximum Contaminant Levels (MCLs) and Action Levels (ALs) for drinking water in California.

MCLs are enforceable primary drinking water standards, adopted into regulation under the Safe Drinking Water Act, which must be met by all public drinking water systems to which they apply. They are risk-management numbers based on comprehensive risk assessments, exposure levels, analytical detection limits, feasibility of removal and removal costs. In cases where no MCL has been estabished, ALs serve as non-enforceable health-based guidance numbers, which are only affected by analytical detection limits. They are provided by the Department as interim guidance for "safe" levels of contaminants in drinking water.

If you have any questions, please call me at (415) 540-2177.

Alexis M. Milea
Alexis M. Milea, P.E.
Acting Supervisor
Standards and Technology Unit

Attachment

State of California
Office of Drinking Water

Department of Health Services

SUMMARY

Maximum Contaminant Level (MCL) and Action Levels (AL)

(All values in milligrams per liter (mg/l) unless otherwise noted)

Constituent	MCL	AL
Inorganic Chemicals		
Aluminum	1.	
Arsenic	0.05	
Barium	1.	
Cadmium	0.010	
Chromium	0.05	
Lead	0.05	
Mercury	0.002	
Nitrate *(as NO_3)*	45.	
Selenium	0.01	
Silver	0.05	
Fluoride		
≤53.7 Degrees Fahrenheit	2.4	
53.8 to 58.3	2.2	
58.4 to 63.8	2.0	
63.9 to 70.6	1.8	
70.7 to 79.2	1.6	
79.3 to 90.5	1.4	
Radioactivity		
Gross Alpha particle activity[1]	15 *(pCi/l)*[2]	
Gross Beta particle activity	50 *(pCi/l)*	
Combined Radium-226 and Radium-228	5 *(pCi/l)*	
Strontium-90	8 *(pCi/l)*	
Tritium	20,000 *(pCi/l)*	
Uranium	20 *(pCi/l)*	
Total Trihalomethanes		
(Sum of bromodichloromethane, dibromochloromethane, bromoform, and chloroform)	0.10	

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[1] Including Radium-226 but excluding Radon and Uranium

[2] pCi/l = pico Curies per liter

Constituent	MCL	AL
Organic Chemicals[3]		
Alachlor *(Alanex)*	Unregulated (b)	0.0002
Aldicarb *(Temik)*	Unregulated (b)	0.010
Aldrin		0.00005
Atrazine *(AAtrex)*	0.003	
Baygon		0.090
Bentazon *(Basagran)*	0.018	
Benzene	0.001	
a-Benzene Hexachloride *(a-BHC)*		0.0007
b-Benzene Hexachloride *(b-BHC)*		0.0003
Bromobenzene *(Monobromobenzene)*	Unregulated (a)	
Bromochloromethane *(Chlorobromomethane)*	Unregulated (b)	
Bromacil *(Hyvar X, Hyvar XL)*	Unregulated (b)	
Bromodichloromethane *(Dichlorobromomethane)*	Unregulated (a)	
Bromoform *(Tribromomethane)*	Unregulated (a)	
Bromomethane *(Methyl Bromide)*	Unregulated (a)	
n-Butylbenzene *(1-Butylpropane)*	Unregulated (b)	
Sec-butylbenzene *(2-Phenylbutane)*	Unregulated (b)	
Tert-butylbenzene *(2-Methyl-2-phenylpropane)*	Unregulated (b)	
Captan		0.350
Carbaryl		0.060
Carbofuran *(Furadan)*	0.018	
Carbon Tetrachloride	0.0005	
Chlordane	0.0001	
Chloroethane *(Ethyl Chloride)*	Unregulated (a)	
2-Chloroethylvinyl Ether	Not Regulated	
Chloroform *(Trichloromethane)*	Unregulated (a)	
Chloromethane *(Methyl Chloride)*	Unregulated (a)	
Chloropicrin		0.050 (0.037)[4]
Chlorothalonil *(Bravo, Daconil)*	Unregulated (b)	
2-Chlorotoluene *(o-Chlorotoluene)*	Unregulated (a)	
4-Chlorotoluene *(p-Chlorotoluene)*	Unregulated (a)	
2, 4-D	0.1	
Diazinon *(Basudin, Neocidol)*	Unregulated (b)	0.014
Dibromochloromethane *(Chlorodibromomethane)*	Unregulated (a)	
1,2-Dibromo-3-chloropropane *(DBCP)*	0.0002	

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[3] Not Regulated: monitoring not required. No MCL or Action Level established.
Unregulated (a): monitoring required for all community and non-transient, non-community water systems.
Unregulated (b): monitoring required for all community and non-transient, non-community water systems if determined vulnerable.

[4] Taste and Odor Threshold

Constituent	MCL	AL
Dibromomethane *(Methylene Bromide)*	Unregulated (a)	
1,2-Dichlorobenzene *(o-Dichlorobenzene)*	Unregulated (a)	0.130 (0.010)[5]
1,3-Dichlorobenzene *(m-Diclorobenzene)*	Unregulated (a)	0.130 (0.020)[5]
1,4-Dichlorobenzene *(p-DCB)*	0.005	
Dichlorodifluoromethane *(Difluorodichloromethane)*	Unregulated (a)	
1,1-Dichloroethane *(1,1-DCA)*	0.005	
1,2-Dichloroethane *(1,2-DCA)*	0.0005	
1,1-Dichloroethylene *(1,1-DCE)*	0.006	
cis-1,2-Dichloroethylene	0.006	
trans-1,2-Dichloroethylene	0.01	
1,2-Dichloropropane *(Propylene Dichloride)*	0.005	
1,3-Dichloropropane	Unregulated (a)	
2,2-Dichloropropane	Unregulated (a)	
1,1-Dichloropropene	Unregulated (a)	
1,3-Dichloropropene	0.0005	
Dieldrin		0.00005
Di(2-ethylhexyl)phthalate *(DEHP)*	0.004	
Dimethoate *(Cygon)*	Unregulated (b)	0.140
2,4-Dimethylphenol		0.40[6]
Diphenamide		0.040
Diuron *(Karmex, Krovar)*	Unregulated (b)	
Endrin	0.0002	
Ethion		0.035
Ethylbenzene *(Phenylethane)*	0.680	
Ethylene Dibromide *(EDB)*	0.00002	
Formaldehyde		0.030
Glyphosate	0.7	
Heptachlor	0.00001	
Heptachlor Epoxide	0.00001	
Hexachlorobutadiene *(Perchlorobutadiene)*	Unregulated (b)	
Isopropyl N (3-chlorophenyl) carbamate *(CIPC)*		0.350
Isopropylbenzene *(Cumene)*	Unregulated (b)	
p-Isopropytoluene *(p-Cymene)*	Unregulated (b)	
Lindane *(gamma-BHC)*	0.004	
Malathion		0.160[7]
Methoxychlor	0.1	
Methyl Ethyl Ketone *(MEK Butanone)*	Not Regulated	
Methyl Isobutyl Ketone *(MIBK)*	Not Regulated	

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[5] Taste and Odor Threshold - Action level for 1,2-Dichlorobenzene and 1,3-Dichlorobenzene is either for a single isomer or for the sum of the 2 isomers.

[6] Taste and Odor Threshold

Constituent	MCL	AL
Methyl Parathion		0.030
Methylene Chloride *(Dichloromethane)*	Unregulated (a)	0.040
Molinate *(Ordram)*	0.02	
Monochlorobenzene *(Chlorobenzene)*	0.030	
Naphthalene *(Naphthalin)*	Unregulated (b)	
Parathion		0.030
Pentachloronitrobenzene *(Terrachlor)*		0.0009
Pentachlorophenol		0.030
Phenol		0.0050[7]
n-Propylbenzene *(1-Phenylpropane)*	Unregulated (b)	
Prometryn *(Caparol)*		
Simazine *(Princep)*	0.01	
Styrene *(Vinylbenzene)*	Unregulated (a)	
2, 4, 5-TP *(Silvex)*	0.01	
1,1,2,2-Tetrachloroethane	0.001	
1,1,1,2-Tetrachloroethane	Unregulated (a)	
Tetrachloroethylene *(PCE)*	0.005	
Thiobencarb *(Bolero)*[8]	0.07	
Toluene *(Methylbenzene)*	Unregulated (a)	0.10
Toxaphene	0.005	
1,2,3-Trichlorobenzene	Unregulated (b)	
1,2,4-Trichlorobenzene (*Unsym-trichlorobenzene)*	Unregulated (b)	
1,1,1-Trichloroethane *(1,1,1-TCA)*	0.200	
1,1,2-Trichloroethane *(1,1,2-TCA)*	0.032	
Trichloroethylene *(TCE)*	0.005	
Trichlorofluoromethane *(Freon 11)*	0.15	
1,2,3-Trichloropropane *(Allyl Trichloride)*	Unregulated (a)	
1,1,2-Trichloro-1,2,2-Trifluoroethane *(Freon 113)*	1.2	
1,2,4-Trimethylbenzene *(Pseudocumene)*	Unregulated (b)	
1,3,5-Trimethylbenzene *(Mesitylene)*	Unregulated (b)	
Trithion		0.0070
Vinyl Chloride *(VC)*	0.0005	
Xylenes *(single isomer or sum of isomers)*	1.750	

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[7] Taste and Odor Threshold - For chlorinated systems

[8] Also listed as a Secondary Drinking Water Standard with MCL of 0.001 mg/l.

Constituent	**MCL**	**AL**
Secondary Drinking Water Standards		
Chloride	250-500-600[9]	
Color	15 *units*	
Copper	1.0	
Corrosivity	Relatively Low	
Foaming Agents *(MBAS)*	0.5	
Iron	0.3	
Manganese	0.05	
Odor--Threshold	3 *units*	
Specific Conductance *(micromhos)*	900-1600-2200[9]	
Sulfate	250-500-600[9]	
Thiobencarb *(Bolero)*[10]	0.001	
Total Dissolved Solids	500-1000-1500[9]	
Turbidity	5 *units*	
Zinc	5.0	

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[9] Recommended-Upper-Short Term

[10] Also listed as a Primary Drinking Water Standard with MCL of 0.07 mg/l.

Chapter 6
Treatment Facilities

Chapter 6

Treatment Facilities

The potential reuse opportunities and associated reclaimed water quality requirements were discussed in Chapter 2, Groundwater Recharge Opportunities, Chapter 4, Demonstration Plant Influent Water Quality, and Chapter 5, Regulatory and Institutional Treatment Requirements. This chapter will identify the treatment facility alternatives that will satisfy various water quality requirement scenarios. Chapter 7 is an in depth discussion of waste solids residuals, with this chapter incorporating the residuals handling costs into the overall treatment costs.

Quality Requirements

The various possible reclaimed water quality requirements were discussed in detail in Chapter 5. Water quality information is summarized in Table 6-1, which presents SJ/SC WPCP average and maximum month effluent quality, proposed California State DOHS Reclamation standards for Groundwater Recharge, some of the EPA drinking water standards, typical Santa Clara Valley groundwater quality, and limited information on the quality of imported water used in the percolation basins.

Groundwater Recharge

Reclaimed water that is used to recharge the groundwater will be diluted and detained for a period of time, eventually becoming part of the potable supply. Therefore, this water must comply or address three general areas of regulations: EPA drinking water standards, state reclamation requirements (Title 22), and the state nondegradation policy. It is not clear how the state nondegradation policy may be applied when its requirements exceed the proposed groundwater recharge regulations.

The EPA drinking water standards can be readily compared to the SJ/SC WPCP effluent quality using the data in Table 6-1. Three parameters of concern are TDS, nitrate, and coliform. In addition, TOC, specific organics, and all chemicals that will produce long-term health effects are also of concern. The effluent metals are well below the drinking water standards. Therefore, for EPA drinking water standards, treatment will be required to reduce the TDS, nitrate, and coliform levels. In addition to the EPA standards shown in Table 6-1, there is a lengthy list of organic compounds that are grouped and measured as TOC. TOC is also indirectly related to the EPA standards.

The Title 22 regulations require that reclaimed water used for groundwater recharge of domestic water supply aquifers be at all times of a quality that fully protects public health. This has generally required case-by-case evaluations, with consideration given to effluent quality, spreading area operations, soil characteristics, hydrogeology, residence time, and distance to withdrawal. To facilitate planning and provide greater

Table 6-1
Water Quality Information

	SJ/SC WPCP Effluent[a]		DOHS Groundwater Recharge[b]	EPA Drinking Water Standard[c]	SC Valley Groundwater[d]	Import Water
	Average	Maximum				
TDS (mg/l)	870		500	500	350	321
Nitrate (as N)(mg/l)	17.0	23.3	10	10	3	<1
Total Nitrogen as N (mg/l)	19.3	25.9	--	--	3.4	<5.1
Arsenic	<2.0	<5	50	50	--	2
Cadmium	<0.5	<0.5	10	10	1 to 2	--
Chromium, Total	1.1	1.8	50	50	<1 to 5	--
Copper	7	9	1,000	1,300	<10 to 50	<5
Lead	<1	<2	50	15	<10 to 30	<5
Mercury	<0.2	0.3	2	2	--	--
Nickel	13	17	---	---	<10	--
Silver	3	4	50	50	<5	--
Zinc	53	76	5,000	5,000	<100	--
Total Coliform (MPN)	2.5	8.0	---	1	--	--
Turbidity (NTU)	1	2	---	1[f]	--	--
TOC (mg/l)	11	16	20/5/16/2[e]	---	0.2 to 1.5	3 to 4

[a] 1991 data. Provided by the SJ/SC WPCP.

[b] Proposed standards, expected to be finallized in 1992.

[c] EPA Primary and Secondary Drinking Water Standards. All Standards listed are primary standards (indicating a relationship between concentration and public health protection) except copper, zinc, and TDS, which are secondary standards (taste and odor related), pH, which is based upon aesthetic criteria, and cyanide, which is health based.

[d] Groundwater Quality Monitoring Program for the Santa Clara Valley Groundwater Basin. Santa Clara Valley Water District, July 1986.

[e] 20% Dilution: 20 mg/l surface recharge, 5 mg/l direct injection.
50% Dilution: 6 mg/l surface recharge, 2 mg/l direct injection.

[f] Scheduled to decrease to 0.5 NTU in June 1993.

Note: µg/l except as noted.

uniformity within the state, a new set of guidelines is currently being developed through a interagency effort of DOHS, the SWRCB, and DWR. These guidelines, to be titled Policy and Guidelines for Groundwater Recharge of Municipal Wastewater, have been published in draft form in 1991. That document has established certain minimum dilution (mixing) requirements for recharge of wastewater in combination with another conventional recharge water source. These dilution requirements apply to the water supply well, not the recharge point, and are subject to the following conditions:

- Treatment level—Secondary treatment or advanced treatment processes such as GAC for the removal of organics
- Vertical separation to maximum groundwater elevations—A minimum of 10 feet required
- Horizontal separation to domestic wells—Minimum separations of 500 and 1,000 feet specified under stated conditions
- Residence time in groundwater—Minimum travel times of 6 and 12 months to domestic wells specified

Based on conversations with the staff of the interagency coordinating committee, it is expected that allowable dilution rates may range from 20 percent with secondary effluent, to as high as 50 percent with GAC. These numbers should be used with caution until the guidelines are officially adopted.

In addition to regulatory requirements, any groundwater recharge system in the Santa Clara Valley may also be required to comply with criteria related to the State's nondegradation policy. That policy is the SWRCB Resolution No. 68-16, Statement of Policy With Respect to Maintaining High Quality of Waters in California. Given the existing quality of groundwater in the Santa Clara Valley as summarized in Table 6-1, primary constituents of concern in this case are TDS, nitrate (NO_3), and TOC. The TDS and nitrate requirements are more restrictive than the EPA drinking water standards.

The water quality of the imported state water currently used for recharge in the percolation basins also provides a standard of water quality. As shown in Table 6-1, the imported water has TOC value of up to 4 mg/l, close to the maximum of 6 mg/l allowed under the draft DOHS groundwater regulations for surface recharge at 50 percent dilution.

TOC Content

In considering standards for treatment plant effluent used for groundwater recharge, it has been suggested that the composition of TOC in import or surface water might reflect a more natural organic content, while TOC in SJ/SC WPCP effluent might reflect a more manmade, industrial content, which might pose a greater risk to public health when injected into the groundwater. The concern is to evaluate the risk to the groundwater by injecting reclaimed water with unknown or hazardous TOC content.

Dr. Richard Bull, a Blue Ribbon Committee member, has stated that, in his experience, no more than 5 percent of the TOC components in domestic waters and wastewaters are usually identifiable. This point is substantiated by the SJ/SC WPCP effluent data, in which average and maximum TOC was 11 and 16 mg/l in 1991, while testing during this same period identified only .081 mg/l specific organic constituents, or 0.7 percent as reported in Table 4-4. If an additional 1.5 mg/l grease and oil in the effluent is assumed to be 100 percent TOC, it would only identify another 14 percent of the total organic components. Tables 4-4 and 4-5 are assumed to be present at the detection limit of 1 mg/l, then an additional 0.124 mg/l of TOC would have been identified, or an additional 1.1 percent of the total average TOC. It is usually assumed that the remaining unidentified TOC is composed of humic and fulvic acids, decomposing plant or animal matter, typically of large molecular weight.

The recommended approach to resolving the TOC content issue is to analyze various samples during pilot testing for organics using a GC mass spectrometer (GCMS) and compare results. The recommended various samples include:

- Groundwater (both chlorinated and unchlorinated)
- Import water
- Reclaimed water
- SJ/SC WPCP effluent/demonstration plant influent
- Treated water from SCVWD Water Treatment Plants (WTPs)
- Hetch Hetchy raw water

A key element in resolving TOC content will be "challenge testing," during the pilot studies, where the demonstration plant influent will be spiked with high concentrations of various manmade organic chemicals and then the reclaimed water effluent will be tested for removal efficiency. The demonstration plant influent and effluent GCMs graphs will be compared to see whether similar spikes exist, indicating spiked chemical breakthrough. William Lauer, a Blue Ribbon Committee member, said that similar challenge testing at the Denver Direct Potable Reuse Demonstration Plant indicated a highly-successful removals efficiency, which led to an increased confidence in the reclaimed water processes.

It has been noted that TOC quantity alone is not the issue, but rather the quantities and health effects of specific organic compounds, identified and unidentified, known and unknown. In the case of known chemicals, the organic constituents may need to be reduced well below existing limits on the basis that the allowable concentration limits may be reduced further at some future time. Reducing overall TOC quantities will hopefully reduce the quantities of compounds of concern. In addition, there is also the possibility that other organic chemicals may be newly found to pose health risks. The draft DOHS groundwater recharge regulations approach the issue of organic compound risk by reducing the maximum allowable TOC as the percent reclaimed water increases and as the recharge method becomes more direct (see Table 6-1).

Separate processes that each remove organics will act as multiple barriers to decrease the risk of process breakdowns and increase the comfort level. Processes that remove organics include high pH, lime, RO, and GAC. Risk from unknowns may also be reduced by increasing process redundancies, especially GAC. Increasing the percent of the treatment plant flow that passes through GAC may be desirable to decrease the risk from unknowns.

During the Blue Ribbon Committee review meeting there was a discussion about expanding the SJ/SC WPCP pretreatment program to try to identify what organics/toxics are used by industry and discharged to the WWTP. Dr. Richard Bull recommended that a limited program be implemented to identify what organics are used in the community and thus might be observed in the wastewater and reclaimed water. Mr. William Lauer commented on the Denver Reuse project experience with this approach. While knowledge of the chemicals used in the community did help select organics subjected to challenge testing, Denver found that this method did not address chemical changes/new compounds created in the industries processes. Thus, Denver relied on complete effluent organic testing rather than effluent analysis for chemicals known to be used. Considering the effort expended for the gain achieved, Mr. Lauer did not think such an expanded pretreatment program was warranted for SJ/SC WPCP.

Another subject discussed during the Blue Ribbon Committee review meeting was about adding the cost of water supply well head treatment to the cost estimates in case future regulations affect previously recharged contaminants. Because this concern also applies to import/surface water and because treatment needs are not defined, no costs are included in the cost estimates.

Tentative Treatment Standards

Pending resolution of outstanding water quality requirement questions raised in Chapter 5, the treatment requirements will be approached based on meeting either of two standards: groundwater nondegradation standards or composite standards.

These two suggested treatment standards are summarized in Table 6-2. The groundwater nondegradation standards are based on average groundwater quality in the Santa Clara basin.

The composite standard derives criteria from several sources. The composite standard is based on treating the reclaimed water to a quality such that, when it is blended with dilution water imported from state or federal water projects, the combined recharge water quality matches the average groundwater TDS and nitrate quality. Regarding TOC concentrations, the composite standard is based on the reclaimed water quality

Table 6-2
Treatment Standards

Standard	Reclaimed Water Concentration			Based On
	TDS (mg/l)	NO_3 as N (mg/l)	TOC (mg/l)	
Groundwater nondegradation	350	3.4	1.0	Limited groundwater data
Composite 20 percent dilution[a]; surface recharge or direct injection	350	-	-	Current average groundwater concentrations
	-	10	-	Import and local surface water currently used in percolation ponds. N = 0-1 mg/l; DOHS draft Groundwater Recharge Regulations allow 10 mg/l or less. Blend to 3.4 mg/l or less.
	-	-	2.5	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 20/5 mg/l.
Composite 50 percent dilution[b]; surface recharge	350		-	Current average groundwater concentrations
	--	5.8	--	Import and local surface water currently used in percolation ponds, N = 0-1 mg/l. Blend to 3.4 mg/l or less.
	--	--	2.5	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 6 mg/l.
Composite 50 percent dilution[b]; direct injection	350	--	--	Current average groundwater concentrations
	--	5.8	--	Import and local surface water currently used in percolation ponds N = 0-1 mg/l. Blend to 3.4 mg/l or less.
	--	--	1.6	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 2 mg/l.

[a] Twenty percent reclaimed water is combined with 80 percent import water/surface water/treated water before surface or injection well recharge.

[b] Fifty percent reclaimed water is combined with 50 percent import water/surface water/treated water before surface or injection well recharge.

meeting the draft DOHS groundwater recharge regulation requirements and having less TOC content than the import water, currently being recharged. The composite standard reclaimed water TDS would be less than or equal to that of average groundwater, or 350 mg/l. The composite standard reclaimed water nitrogen concentration would be between 5.8 and 10 mg/l nitrate as N, and the blended water concentration would be less than or equal to the average groundwater or 3.4 mg/l as total nitrogen. Total nitrogen is anticipated as the basis for the DOHS groundwater recharge standard because all forms of nitrogen will convert to nitrate once in the groundwater. The composite standard reclaimed water TOC concentrations would be between 1.6 and 2.5 mg/l, also meeting the draft DOHS groundwater recharge standards. These TOC concentrations would also be less than or equal to the imported state water concentrations, or 4 mg/l. Note that the filtered dilution water TOC may exceed the average groundwater TOC concentration.

For example, at a 50 percent dilution, assuming all dilution occurs before surface recharge, 50 percent of recharge water containing 6 mg/l nitrogen can be combined with 50 percent import or local surface water containing 1 mg/l nitrogen to produce a blend with 3.4 mg/l nitrogen.

Direct Injection Requirements

Groundwater recharge using direct injection wells also has water quality requirements to minimize well maintenance and maximize years of service. Excess suspended solids in direct injection recharge water will tend to foul the injection well, and so it is recommended that the suspended solids concentration be maintained at 1 mg/l or less. Biological growth in the injection well will also tend to foul the well screen, and so a chlorine residual of 1 mg/l is recommended at each well.

Treatment Requirements

The existing SJ/SC WPCP provides filtered, disinfected effluent of consistently high quality. To meet the reclaimed water quality requirements outlined above, however, additional treatment will be necessary. Depending on the final required treatment standards, the treatment facility may be required to perform the following additional functions:

- Filtration
- Disinfection
- Metals removal
- Demineralization
- Nutrient removal
- Organics removal

Another treatment concern is bio-fouling or chemical-fouling of the SCVWD percolation ponds. Because positively charged sodium has the potential to chemically bond with the negatively charged clay particles, adequate sodium removal during demineralization will be verified during pilot testing. Because a high TOC has the potential to cause higher biological growth rates in the percolation ponds, the effluent TOC will be carefully monitored.

As discussed with Blue Ribbon Committee members, additional treatment processes, such as air stripping and biologically activated carbon, will be evaluated in the next Plan of Study phase of project work. Process criteria will also be refined, such as RO percent recovery, possibly increasing recovery from 80 percent to as high as 95 percent.

Filtration

Although effluent turbidity from the existing filters is consistently below 2 NTU, the process does not specifically meet Title 22 criteria (...coagulated, clarified, filtered,...) because of a lack of chemical addition, nor the criteria established by DOHS for direct filtration. However, communications with the DOHS on the nonpotable reclamation project have indicated that DOHS is satisfied that the SJ/SC WPCP effluent meets the regulatory requirements without additional filtration.

Filtration is also used as a polishing step after lime soda softening as a pretreatment step for RO. In this RO pretreatment application, the filtration bed captures residual suspended solids and guards against clarification upsets. In the event that a clarifier upset occurs, the carry-over solids will be removed in the sand filters. The RO membranes also have an upstream cartridge filter for additional protection, and so there is little danger from sand carry-over from filtration to RO.

Disinfection

The existing disinfection system at the SJ/SC WPCP is currently operated to meet a disinfection standard of 23 MPN total coliform per 100 ml. The average coliform count for SJ/SC WPCP for the last 3 years is 2.5 MPN per 100 ml. Chlorine contact time is approximately 45 minutes at peak flows.

The Title 22 guidelines for chlorine disinfection specify a 2-hour contact time and 5 mg/l residual. However, this guideline is conservative and flexible if it can be demonstrated that sufficient virus kill can be achieved. The proposed groundwater recharge standards being formulated by DOHS specify a 7-day average for coliforms of 2.2 MPN per 100 ml and a maximum of 23 MPN per 100 ml. To meet Title 22 criteria, additional chlorination and contact time must be provided.

Currently, plant effluent is given a 14 to 16 mg/l dose for a 45-minute contact time and then dechlorinated before discharge to the outfall channel. Dechlorination doses and contact times will be developed in the next phase of work. For the nonpotable reclamation of SJ/SC WPCP effluent DOHS has indicated that it will accept an additional minimum modal time of 45 minutes with a chlorine residual of at least 5 mg/l. This is based on nonpotable flow diversion after dechlorination at the existing SJ/SC WPCP facilities.

For the nonpotable reclamation of SJ/SC WPCP effluent, a portion of the effluent is diverted, rechlorinated, and pumped to a storage reservoir common to both the nonpotable and groundwater recharge reclamation treatment plants. The rechlorination provides an additional 45-minute contact time with a 5 mg/l residual. This requirement is stringent since the nonpotable portion of this water will involve human exposure during reuse.

The groundwater recharge treatment plant processes will not reintroduce virus, and the multiple-process units provided at the WPCP and the proposed groundwater recharge treatment provide redundancy should any individual treatment process fail.

It is expected that there will be limited human exposure to the groundwater recharge treatment plant effluent, and only a minimal residual of approximately 1 mg/l will be required in the groundwater recharge treatment plant effluent to control growths in the conveyance pipeline and/or direct injection wells.

The original Reconnaissance Investigation recommended ozonation at the groundwater recharge reclamation plant as the preferred method of disinfection. A potential problem with chlorination is that disinfection by-products, such as THMs, could percolate into the groundwater when reclaimed water is used for recharge. This problem may be eliminated with ozonation. However, ozonated by-products may be formed, depending on the type of organics present, and may cause other health-related problems. In addition, it was speculated that ozone would improve the direct filtration and denitrification processes. It now appears that the potential for THM formation is small, and that THMs may degrade in the groundwater. As summarized in Table 4-4, tests of SJ/SC WPCP effluent have revealed chloroform concentrations of 6.5 ug/l, bromodichloromethane concentrations of 6 μg/l, chlorodibromomethane concentrations of 3.5 μ/gl, and bromoform below the detection limit, for a total of 16 μgl THMs. This total is significantly less than existing 100 ug/l and proposed 50 ug/l total THM standards in drinking water. Disinfection by-products will be tested during pilot testing, as recommended in Table 4-6. Anticipated improvements in the filtration process efficiency from ozone appear to be negligible. Therefore, it does not appear that there are any advantages to using ozone and since ozonation is more expensive, it has been rejected as an alternative.

The process flow scheme for chlorination of the final recharge water is designed to control regrowth in the distribution system, with approximately 1 mg/l chlorine dose. It is anticipated that dechlorination may be required for the water that is discharged into the percolation ponds because of the aquatic toxicity of chlorine.

Dechlorination

Complete dechlorination will probably be required for any reclaimed water used for surface groundwater recharge. This is based on the assumption that a chlorine residual discharged to the percolation ponds would affect aquatic life either in the ponds or in the streams into which the ponds discharge. Aquatic life might include fisheries, mosquito control fish (*Gambusia affinis*), and insects. A slight chlorine residual will be desirable for control of slime growth in the pipeline. Consequently, the most practical method of dechlorination would be to provide remote stations at each point of discharge for injecting sodium metabisulfite or sulfur dioxide.

Metals Removal/RO Pretreatment

Lime Soda

Chemical precipitation using lime soda as the coagulant is also typically required as a pretreatment step before RO, removing particulates and suspended solids and creating a pathogen barrier with the high pH. High pH lime treatment can also be used for enhanced metals removal with or without the addition of soda ash for softening. The complete process includes coagulation of the wastewater with lime and soda ash, followed by flocculation, clarification, recarbonation, and filtration. Lime soda softening functions by adding lime to raise the pH to about 11, at which point calcium precipitates to calcium carbonate ($CaCO_3$) and magnesium precipitates as magnesium hydroxide ($Mg(OH)_2$). Soda ash (Na_2CO_3) is added if the water is deficient in carbonate alkalinity. Soda ash is used to remove noncarbonate hardness. Because of the SJ/SC WPCP effluent water chemistry, soda ash may not be required in this application. The high lime process normally removes silica and most metals in carbonate or hydroxide precipitate. It is necessary to remove silica down to levels that do not rapidly foul the RO membrane. Although a hot lime process at elevated temperatures would significantly increase the silica removal percentage, ambient temperature removal rates will likely provide sufficient silica removal. The SJ/SC WPCP effluent has a very low concentration of metals, near the solubility limits, and so the anticipated removal of metals such as lead, nickel, and mercury is uncertain. Pilot testing is needed to determine what metals are removed in the lime sludge and thus what metals remain for removal in the RO process. These factors then affect the RO brine disposal options.

A significant by-product of lime soda softening is lime sludge. Approximately two pounds of sludge are produced for every pound of lime added; in this case, that is about 5,000 pounds per million gallons produced by the process. Lime sludge is typically thickened (supernatant recycled to the plant influent), dewatered by plate-and-frame presses, and trucked to a landfill.

An influent pump station is included in the scope and cost estimate for lime treatment. Costs for lime sludge handling are based on the 1989 In-Plant Metals Removal Study and will be updated in the next phase of work. Costs for recycle equalization and pumping are also included in the sludge handling cost estimate.

Additional metals removal will be required from the lime soda process effluent. Reverse osmosis is an effective method for removing metals to very low levels. Removal rates for different metals are anticipated to vary from 35 to 95 percent. Pilot testing will be required to confirm RO process efficiency at these low levels. The RO reject brine will also require additional metals removal before disposal. This additional treatment will also use lime precipitation.

The recarbonation step adjusts the pH from about pH 11 back down to neutral. However, the effects of recarbonation are hard to predict and must be evaluated on a case-by-case basis. Bench-scale testing would be necessary to verify that an increase in TDS does not result. Bench-scale testing would also determine whether single- or double-stage recarbonation is most economical. Depending on the carbonate chemistry of the SJ/SC effluent, TDS reductions may be possible with two-stage recarbonation. TDS removal is not a limiting factor in most of the presented alternatives. Lime treatment costs are based on single-stage recarbonation and no change in TDS in this unit process.

Nanofiltration

Nanofiltration is a type of RO process. As with other RO processes, it relies on membranes to obtain the desired result, which in the case of nanofiltration, is the softening of water.

Nanofiltration is a so-called "Loose" RO membrane type of system. The unit is constructed to operate at a lower pressure than conventional RO (i.e., 100 psi versus 300 psi). It allows certain ions to pass that RO would remove and has been used successfully to soften groundwater in Florida.

Its major advantage over conventional softening processes is that chemicals are not used (other than for minor pH adjustment); therefore, there is no bulky sludge to dewater and dispose.

Its major disadvantage is that organic fouling would be a substantial problem; the organic removal processes would likely be needed before the nanofiltration.

Conventional lime softening processes not only remove calcium and magnesium but any residual metals, nonparticulate organics, and pathogens, thereby providing a significant safety factor to downstream processes. Nanofiltration does not provide the same level of safety factor.

Using nanofiltration followed by conventional RO as a two-step treatment system with the goal of avoiding chemical usage/sludge generation, has not been used or studied to date. A water source such as tertiary treated wastewater will have a deleterious effect on the production rates of the membrane systems; therefore, there would have to be pretreatment units before the membrane processes. The treatment process would therefore not be a single two-step process but a three- or four-step process. Since there is a so-called reject stream that constitutes 20 to 40 percent of the total flow to each membrane step, the overall percentage of recovery of treated water would range from 50 to 60 percent.

Because it is an untried process variation that does not offer the safety of conventional process nor is it significantly different from a conventional R.O. system (in its fouling characteristics), nanofiltration was rejected in this evaluation.

Microfiltration

Microfiltration is a pressure driven membrane process using polypropylene hollow fiber membranes to remove particles and some colloids in the 0.2 to 0.8 µm range. Component separation is achieved by simple membrane sieving or filtering, and sometimes by more complex interactions with rejected substances that collect at the membrane surface. The microfiltration membrane process typically operates at 10 to 30 psi and can be used with or without filter aid chemicals. Microfiltration influent typically flows on the outside of the fiber, with the permeate flow moving from the outside to the inside of the fiber. A periodic air backwash system produces an approximate 5 percent microfiltration waste stream, primarily containing organic suspended solids. This waste stream would then be treated by lime softening to remove metals, with the effluent being discharged to the sanitary sewer or to San Francisco Bay.

Results from limited bench testing of domestic wastewater treatment effluent from a confidential CH2M HILL client indicate the following microfiltration removals:

.2 µm Membrane Pore Size—No Chemical Addition
    16% TOC
    44% Orthophosphate
    50% TOT Phosphate
    30% TKN
    0% Nitrates and Ammonia

.8 µm Membrane Pore Size—Ferric Chloride Addition
    37% TOC
    80% Orthophosphate
    90% TOT Phosphate
    44% TKN
    0% Nitrates and Ammonia

Further studies would serve to optimize the type and amount of prefilter chemical required, if any. The goal would be to arrive at the best process to reduce the potential fouling load on the RO units. Microfiltration has the advantage of a "rugged" media that would not be as affected by the presence of organics as are RO membrane processes and that can be treated with stronger cleaning solutions without as much concern for degrading the membrane. The use of a microfilter of .45 µm or smaller, in combination with an appropriate filter aid, should be capable of removing almost all single-cell and larger life forms, as well as particles remaining in the water after other processes.

An influent pump station is included in the scope and cost estimate for microfiltration.

The advantages of the microfiltration process:

- Excellent solids removal efficiencies
- Little or no sludge produced
- Relatively compact in size
- Rugged media
- Relatively low energy usage
- No brine or reject stream

The disadvantages are:

- Backwash water is required (approximately 5 percent of total flow)
- Not fully proven to extend RO operating cycle
- Moderate O&M due to membrane replacement costs (but less than lime and sludge O&M costs)

Demineralization

To comply with nondegradation requirements for groundwater recharge, it is assumed that a demineralization step will be required to reduce reclaimed water TDS from approximately 870 mg/l (existing SJ/SC WPCP effluent quality) to approximately 350 mg/l. Based on present data, it does not appear that additional metals must also be removed to meet groundwater recharge requirements. Reverse osmosis is the most feasible treatment option (as discussed in the 1989 Technical Memorandum No. 4) given these requirements and the expected quality of filtered effluent. The driving force will be high pressure RO influent, typically between 150 and 400 psig.

The electrodialysis reversal (EDR) and reverse osmosis (RO) membrane processes were considered for demineralization, while RO is a pressure-driven membrane process. EDR is an electrically driven membrane process. EDR was not selected because of the lack of organics removal. For planning purposes, the following RO characteristics are assumed:

- TDS rejection rate of 93 percent (efficiency of TDS concentration reduction)
- Recovery rate of 80 percent (ratio of RO product water to RO inflow) in a two-stage RO process. (A recovery rate of 90 or 95 percent will be evaluated during the next phase of work.)

Based on these characteristics and the TDS removal accomplished in lime soda pretreatment, one approach is to blend approximately 60 percent RO product stream to 40 percent bypass stream to achieve a target concentration of 350 mg/l on a long-term basis. A more conservative approach, which will result in even higher quality water, is to process 100 percent of the flow through RO. While this will result in higher treatment costs, this approach also provides a complete barrier for reliable treatment and greater public acceptance. It will also reduce the nitrate and TOC content down to levels that will require much smaller flowrates to be treated in denitrification filter and GAC bypass flowstreams.

The RO process works by pressurizing the influent and passing it through a semipermeable membrane. The membrane is permeable to water and impermeable to a portion of the impurities, such as dissolved salts. The pressure drives a large portion of the influent water across the membrane (product water) and leaves a majority of the impurities behind (concentrate). Several RO membrane elements are combined in one pressure vessel. First-stage vessels process the influent water, while second-stage vessels further process concentrate collected from the first stage vessels.

Pretreatment of RO influent would first consist of hardness, silica, and metals removal (via lime or lime soda addition, coagulation, flocculation, clarification, and recarbonation) and filtration, as discussed in previous sections. If the chlorine into the RO unit exceeds recommended levels, dechlorination may be required. Additional RO pretreatment includes sulfuric acid addition for pH adjustment, chlorine addition as a biocide for control of biological membrane fouling, and scale inhibitor addition for control of membrane fouling because of scale formation. The use of antiscalant chemicals maintains metals in solution in order to not foul the membranes. One or more portable cleaning solution skids would be used to periodically flush out the RO units. Caustic soda would be added to the product water as a post treatment to adjust pH and control water corrosivity. Additional lime could be added and mixed to create a nonaggressive water, either saturated or slightly supersaturated with calcium. During the next phase of work conveyance pipeline materials which are compatible with the aggressive water will be considered enabling the RO effluent to be blended while retaining low TDS water for recharge. A packed tower degasifier may be required to remove excess carbon dioxide from the product water. During the next phase of work, RO effluent air stripping will be evaluated for volatile organic compounds and carbon dioxide removal.

RO Concentrate (Brine)

Handling the RO reject or concentrate (brine) flow is a significant issue, addressed at length in Chapter 7, Treatment Residuals. Where possible at other installations, the concentrate is simply added to the wastewater treatment plant discharge such as is done at Water Factory 21. A new shallow water discharge into the Bay may not be allowed, because of the stringent discharge standards for metals. A number of installations in Florida dispose of the concentrate by injecting it into deep, nonpotable aquifers; however, such aquifers do not exist in the Santa Clara Valley. Smaller, industrial facilities discharge the concentrate into the sanitary sewer system.

James M. Montgomery Consulting Engineers, in their report titled, Metals Removal Study for the Palo Alto Regional Water Quality Control Plant, October 1989, evaluated the issue and considered a number of disposal options, including evaporation ponds, heat evaporation, hauling offsite, lime precipitation, discharge in a Bay outfall, and discharge in an ocean outfall. Each alternative presented significant problems. The final conclusion, however, was that the most feasible alternative was a $26.5-million pipeline to enable discharge of the concentrate in the Pacific Ocean. Such a pipeline for the SJ/SC WPCP would be significantly more costly because of the greater length and capacity required. There are also major concerns regarding the environmental impacts and mitigation requirements associated with this alternative.

There appear to be several potential methods for handling the RO concentrate from the groundwater recharge reclamation facility. The first, referred to as lime brine treatment, is to chemically treat the concentrate and cause the metals to precipitate. The treated lime effluent is returned to the Bay using a new outfall. RO brine would not be returned to either SJ/SC WPCP influent or effluent because the high metals content would affect WPCP's NPDES permit compliance. Even though the metals are concentrated in the RO concentrate stream, the concentrations are still quite low, but above the present basin plan limits. Thus a new outfall with diffuser would be required. The new outfall would utilize a 10:1 dilution diffuser sized for 5-mgd flow. With this dilution all basin plan metal concentration limits would be met, except for mercury. Proposed mercury limits based on site-specific studies, currently under RWQCB consideration, would bring mercury into compliance using a 10:1 dilution rate. There is a lack of data from operating facilities on metals removals at these low concentrations and so pilot testing will be required to confirm removal rates. Multispecies bioassays will also require pilot testing. A second option, referred to as zero brine discharge, is to further treat the brine lime effluent with RO seawater type membranes. These membranes are selected to concentrate brine at 80 percent recovery. Seawater RO brine would be further concentrated through vapor compression evaporation and forced circulation crystallization to produce a crystalline solid for encapsulation and land disposal. This is a zero brine discharge option in that the brine treatment effluent is of a quality which matches or exceeds that of the RO effluent, and so 97 percent of the brine flow is returned to the RO effluent stream. This in effect reduces the plant influent flow by 20 percent and thus reduces the associated costs accordingly. The effectiveness and estimated costs associated with these types of chemical treatments are presented in Chapter 7. Cost estimates are listed in the Chapter 8, Conveyance Systems, for additional brine conveyance piping to the Bay when treating brine with lime/soda only.

Limited bench-scale testing has been done to assess, on a very preliminary basis, the practicality of chemically treating RO concentrate. The testing, which was done on concentrate samples from Water Factory 21, is inconclusive. Metals removals in the range of 40 to 90 percent were obtained using a combination of lime and ferric salts. Test reproducibility was low, however. Although it is believed that the processes can be made to work, the associated costs are uncertain. The processes must be verified through pilot testing.

Nutrient Removal

Nitrogen concentrations in the existing plant effluent average approximately 18 mg/l nitrate and 2 mg/l ammonia (both measured as N). Current nitrogen concentrations in the groundwater are approximately 3 mg/l. Therefore, an 85 percent removal would be required to meet an antidegradation policy. The RO process should be capable of removing approximately 65 percent of the nitrate; however, overall removals will depend on the amount of the bypass flow (if any), the RO membrane type, and the operating pH. Some additional nitrogen removal will thus be required to meet reclaimed water quality requirements for groundwater recharge. Given the existing SJ/SC WPCP configuration (including full nitrification), two major options for nitrogen removal are available:

- Denitrification filters—An anaerobic process in which nitrate is converted to nitrogen gas. The addition of a carbon source such as acetate or methanol may be required.

- Biological nutrient removal—A modification to the activated sludge process in which aeration basins are subdivided into anaerobic, anoxic, and aerobic zones to promote nitrification and denitrification reactions.

The biological nutrient removal process would involve significant modification and extensive rerouting of flows through the activated sludge and nitrification processes at the SJ/SC WPCP. At this time, SJ/SC WPCP does not plan to implement complete denitrification of all or part of its flow at the treatment plant. Consequently, denitrification filters, which can be added in a separate, much smaller treatment facility, are a more feasible option at this stage of investigation.

The denitrification filters are a biological submerged granular media type. The fixed film denitrifying organisms use nitrate, along with carbon and phosphorous to convert nitrate to nitrogen gas. Because of the low available carbon, it is assumed that methanol will be added as a carbon source. A combination of air and water is used during the backwash cycle. The backwash solids are settled in the plant washwater settling basin and recycled back into the lime clarifiers.

The nitrate concentration in the denitrification filter effluent is typically assumed to be 2 mg/l (as N), with a loading rate of 3 gallons per minute per square foot (gpm/sf). We have assumed that the groundwater recharge treatment plant operates at a constant flow, unaffected by diurnal variations that affect most typical WWTP. Thus, the loading rate used is 50 percent higher than that typical for WWTPs and may be further increased once the constant flow kinetics are established during pilot testing.

Granular media filters may be operated for combined direct filtration suspended solids removal and denitrification. This option should be further explored during pilot testing.

Organics Removal

No specific organic compounds, other than the disinfection by-products such as chloroform, have been identified as potential problems. In addition, it is anticipated that only 10 to 30 percent of the organics will be identifiable. The particular TOC composition was discussed in the beginning of this chapter under Quality Requirements and so will not be repeated in this section. Thus, only TOC removal is discussed in this section. TOC concentrations in the existing plant effluent average approximately 11 mg/l, with maximum day concentrations of approximately 15 mg/l. Organics removal down to 1 to 2 mg/l may be required for groundwater recharge. Two methods of removing TOC are RO and GAC. Removal of TOC by RO is normally considered secondary to desalination, but rejection (removal) rates of 70 to 90 percent are common. GAC is typically used for removing organics. A TOC removal rate of 50 to 60 percent is normally achieved with GAC. The actual removal rate for both RO and GAC is dependent on the molecular weight of the organic compounds in question, both are more efficient as the molecular weight increases. Other factors that affect the GAC removal efficiency are the type of carbon used, loading rates, and carbon age. Actual removal rates must be determined by pilot testing.

RO is projected to have a higher TOC removal efficiency than GAC (90 versus 60 percent). RO has a higher unit cost than GAC and also produces the previously discussed concentrate. RO is, however, necessary for removal of TDS and metals. RO also has the disadvantage of requiring the upstream pretreatment processes to be sized to accommodate both the product and concentrate flow rates.

The anticipated flow scheme includes two downflow carbon contactors in series, but the optimum configuration must be determined during pilot testing. Downflow carbon contactors in the final stage tend to trap carbon fines and prevent them from increasing the TOC in the reclaimed water effluent. The GAC backwash water would be sent to the reclamation plant washwater settling basins and then recycled back to the lime clarifiers.

Spent carbon will either be regenerated onsite in a multihearth type furnace or trucked offsite for commercial processing at an existing facility. Carbon storage will be provided. If onsite regeneration is implemented, regeneration gas afterburners and scrubbers will be supplied to comply with air quality permit requirements. This treatment of emissions should adequately address the issue of organics in the off-gas, but permitting this facility is still expected to be difficult if not impossible. Because of the permit issues, both on- and offsite regeneration will be considered, but offsite regeneration costs will be used for alternative cost estimates.

Further testing of SJ/SC WPCP effluent and existing groundwater may indicate that there are specific organic compounds of concern. If this is the case, then the GAC pilot testing will optimize removal of those specific compounds, as well as the overall TOC removal.

Biologically active carbon (BAC) was discussed during the Blue Ribbon Committee review meeting, especially regarding the steady state organic removal performance observed at the Denver Reuse Demonstration Plant. This option will be further considered during the next phase of work and should be demonstrated during the pilot testing.

Treatment Alternatives

The treatment alternatives illustrate process flow schemes that can be used at the groundwater recharge treatment plant to perform the combination of functions described previously and produce reclaimed water. The processes described here were selected for the specific reclamation opportunities in this project and based on information from reclamation projects in Denver, Colorado; Tampa, Florida; Manassas, Virginia (Upper Occoquan Sewage Authority); and Richmond, California (EBMUD).

The 1990 Reconnaissance Report presented alternatives which outlined the phased construction of first small and then larger nonpotable and potable reclamation projects. The phased construction approach is no longer considered most suitable for meeting the overall project constraints. At this time the nonpotable project facility plan has been developed to be compatible with a potable or groundwater recharge project. The treatment alternatives presented in this updated groundwater recharge report now address options for meeting different water quality standards and for providing a multi barrier approach to provide maximum process reliability and public confidence. Alternative 2 as presented below is similar to Alternative 4 as presented in the 1990 Reconnaissance Report.

Design criteria were developed for each process using SJ/SC WPCP effluent water quality data and results generated from the other projects. Each process was sized to treat SJ/SC WPCP maximum month effluent concentrations. Bench-, pilot-, and perhaps demonstration-scale tests will be required to refine design criteria and determine if treatment train modifications are needed.

Flow Rate Quantity

All of the alternatives presented are based on 20-mgd continuous reclaimed water production. Plant influent varies between 20 and 25 mgd, depending on the type of RO brine treatment. With the lime brine treatment, 25-mgd plant influent is required to accommodate the 20 percent (5-mgd) brine flow that is discharged to the Bay. With the zero brine discharge treatment, only approximately 20-mgd plant influent is required, as 97 percent of the brine is treated to RO product water standards and combined with the RO effluent flow.

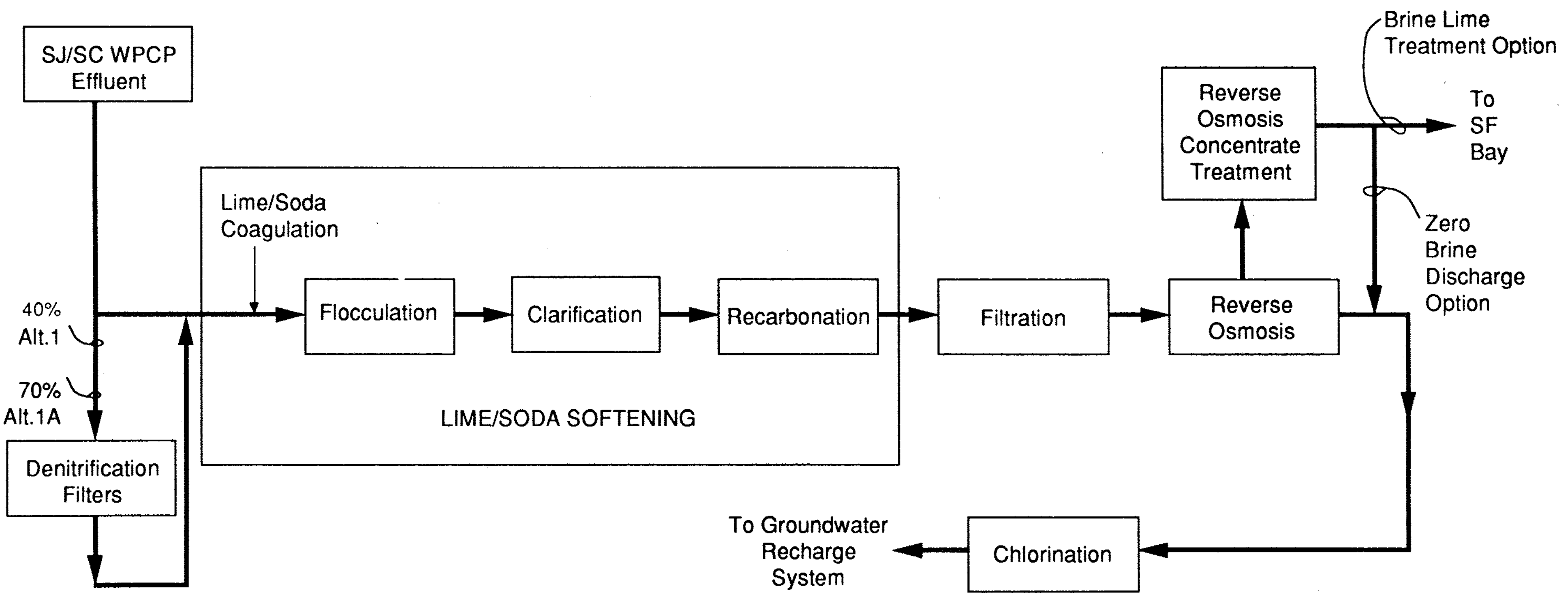
Treatment Standards

The required treatment standards are not yet finalized and so various treatment alternatives are presented, some of which are more versatile as to the range of treatment standards which they are capable of meeting. The most versatile treatment alternatives are capable of treating the reclaimed water to meet either a composite standard or the more stringent groundwater nondegradation standards, both discussed at the beginning of this chapter. Treatment Alternatives 1A and 4A are able to produce reclaimed water that meets the groundwater nondegradation standard. The treatment alternatives able to meet only the composite standards are also presented for cost benefit comparisons.

Treatment Alternative 1

This system, shown on Figure 6-1, is the most comprehensive alternative with a proven performance record. Partial flow denitrification first reduces the nitrate levels, followed by full-stream lime soda softening and filtration for metals reduction and RO pretreatment. Full-stream treatment through RO units removes TDS, nitrate, TOC, and metals. Full-stream RO also provides multiple barrier protection for water quality reliability and public acceptance. Finally, the product water is chlorinated with approximately a 1 mg/l residual to limit growth in conveyance pipelines.

Treatment Alternative 1 is capable of treating the reclaimed water to meet either the composite standards or the groundwater nondegradation standards. Treatment Alternative 1 meets composite standards by treating 50 percent of the plant flow through the denitrification filters, and groundwater nondegradation by treating 70 percent of the plant flow through the denitrification filters. Water quality data and cost estimates refer to Alternative 1 when meeting composite standards and Alternative 1A when meeting groundwater nondegradation standards. GAC is not required, due to the TOC removals in the lime and RO treatment units.



POSSIBLE TREATMENT STANDARDS

- Groundwater Nondegradation (Alt. 1A)
- Composite (Alt. 1)

  TDS - Groundwater Nondegradation
  NO3 - DOHS draft Groundwater Regulations
  TOC - Import/Percolation Pond Water Quality

VOLUME

- 20 mgd Product Water
- 25 mgd Influent - Brine Lime Treatment Option
  20 mgd Influent - Zero Brine Discharge Option

FIGURE 6-1
TREATMENT ALTERNATIVE 1

Although not required to meet groundwater nondegradation standards, full-stream GAC may be desirable as an additional barrier against organics in the groundwater recharge water. Full-stream GAC is not included in Alternative 1 and 1A cost estimates.

RO brine is treated by either lime brine or zero brine discharge methods. With lime brine treatment, the effluent is discharged to San Francisco Bay using a new pipeline and outfall with diffuser. With zero brine discharge treatment, the effluent water quality matches the RO effluent water quality, and so both are blended together as RO product water. With lime brine treatment, 20 percent of the treated water is discharged as brine from the groundwater treatment plant. With zero brine discharge treatment, no brine is discharged so the groundwater treatment plant influent can be 20 percent less than the plant influent with lime brine treatment.

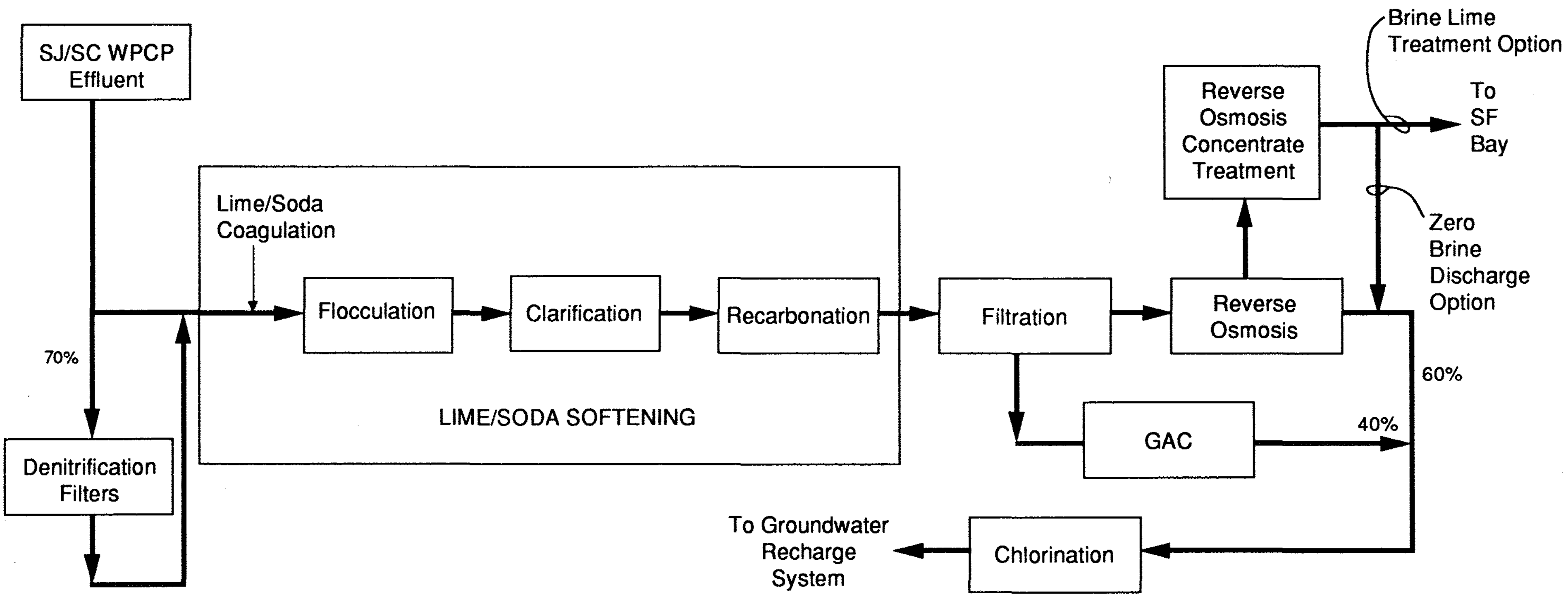
Important process design criteria and performance data to be determined during pilot testing include parameters such as: lime, soda, carbon dioxide, and coagulant chemical requirements; metals and TOC removal data by lime soda softening; sedimentation rates; maximum filtration rates and filter run lengths; RO membrane cleaning frequency and flux decline rate; chlorine dose requirements and decay rates; disinfection by-products formed; and general loading rates and resulting performance data for all process units. Each wastewater is unique and thus there are many unknowns when projecting alternative costs and final water quality.

Treatment Alternative 2

Treatment Alternative 2, shown on Figure 6-2, differs from Treatment Alternative 1 in that the plant flow is split between the RO and GAC process units, treating 60 percent of the flow in the RO system to meet a TDS of 350 mg/l, and treating the remaining 40 percent of the flow in the GAC unit. The percentages of flow splitting between RO and GAC have been determined in an effort to optimize cost and performance. The flow through RO is set to achieve these treatment requirements and minimize cost. GAC is used for the remaining flow because it is less costly while still removing TOC.

This alternative results in a water quality meeting the composite standards only and only for direct injection recharge at 20 percent reclaimed water. The projected water quality from Alternative 2 is 2.5 mg/l TOC, which exceeds the DOHS criteria of 2 mg/l TOC for direct injection at 50 percent. Because of the reduced RO treatment, 70 percent of the plant influent must be diverted through the denitrification filters to meet the composite standards.

RO brine is treated by either lime brine or zero brine discharge methods. With lime brine treatment, the effluent is discharged to San Francisco Bay using a new pipeline and outfall with diffuser. With zero brine discharge treatment, the effluent water quality matches the RO effluent water quality, and so both are blended together as RO product water. With lime brine treatment, 20 percent of the treated water is



POSSIBLE TREATMENT STANDARDS

- Composite (Alt. 2)

  TDS - Groundwater Nondegradation
  NO3 - DOHS draft Groundwater Regulations
  TOC - Import/Percolation Pond Water Quality

VOLUME

- 20 mgd Product Water
- 25 mgd Influent - Brine Lime Treatment Option
  20 mgd Influent - Zero Brine Discharge Option

FIGURE 6-2
TREATMENT ALTERNATIVE 2

discharged as brine from the groundwater treatment plant. With zero brine discharge treatment, no brine is discharged so the groundwater treatment plant influent can be 20 percent less than the plant influent with lime brine treatment.

Additional important process design criteria and performance data to be determined during pilot testing include parameters such as: methanol requirements; GAC backwash and regeneration frequency; and GAC loading rates and resulting performance data.

Treatment Alternative 3

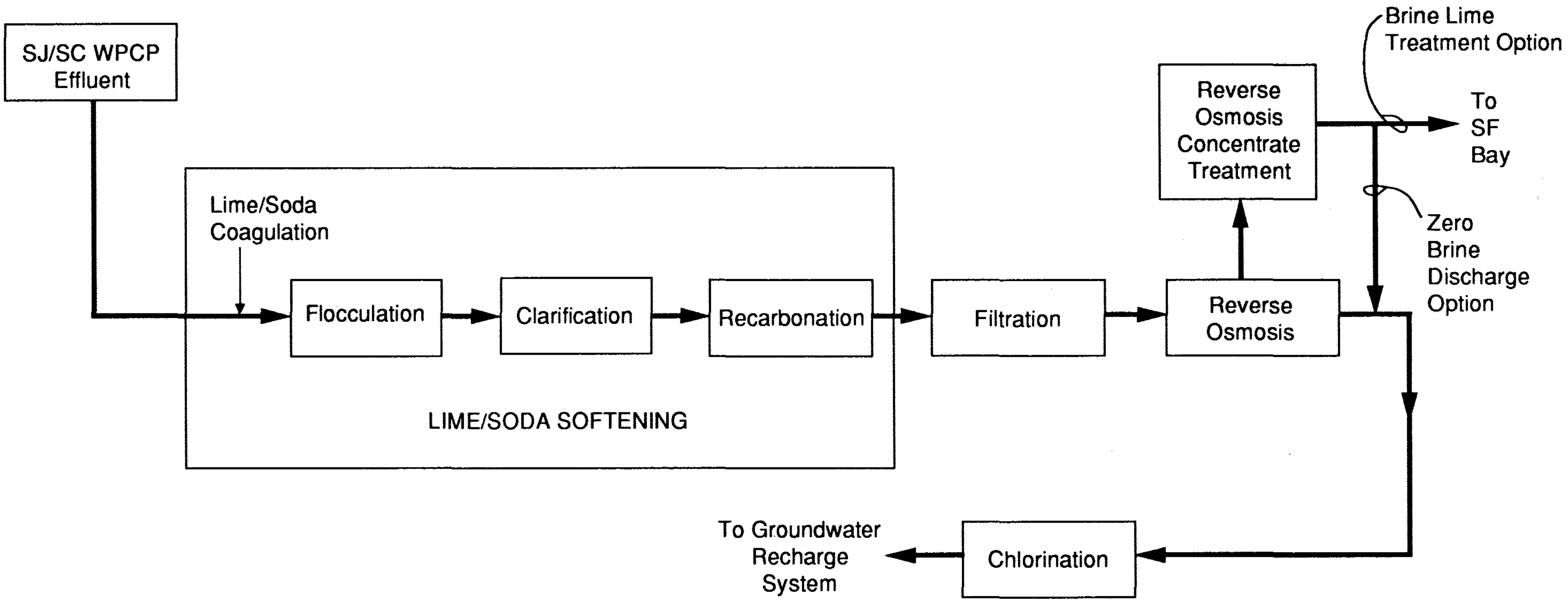
Treatment Alternative 3, shown on Figure 6-3, is essentially Treatment Alternative 1 without the denitrification or GAC process units. This results in a water quality meeting the composite standards.

Treatment Alternative 4

This system, shown on Figure 6-4, has the potential to meet both the groundwater nondegradation and composite treatment standards, similar to Treatment Alternative 1. This treatment scheme uses microfiltration as an innovative alternative to lime soda and filtration as the pretreatment step before RO. Partial flow denitrification first reduces the nitrate levels, followed by full-stream microfiltration. Full-stream treatment through RO units then removes TDS, nitrate, TOC, and metals. Full-stream RO also provides multiple barrier protection for water quality reliability and public acceptance. Partial flow treatment with GAC polishes Alternative 4A product water to meet groundwater nondegradation TOC requirements. Finally, the product water is chlorinated with approximately a 1 mg/l residual to limit growth in conveyance pipelines.

Treatment Alternative 4 is capable of treating the reclaimed water to meet either the composite standards or the groundwater nondegradation standards. Treatment Alternative 4 meets composite standards by treating 50 percent of the plant flow through the denitrification filters, and groundwater nondegradation by treating 69 percent of the plant flow through the denitrification filters. Water quality data and cost estimates refer to Alternative 4 when meeting composite standards and Alternative 4A when meeting groundwater nondegradation standards. GAC is not required to meet composite standards, but is required in Alternative 4A to meet groundwater nondegradation standards, because of the lower TOC concentrations required by the nondegradation standards.

Although not required to meet groundwater nondegradation standards, full-stream GAC may be desirable as a redundant, additional to improve reliability barrier against organics in the groundwater recharge. Full-stream GAC is not included in the Alternative 4 and 4A cost estimates.



POSSIBLE TREATMENT STANDARDS

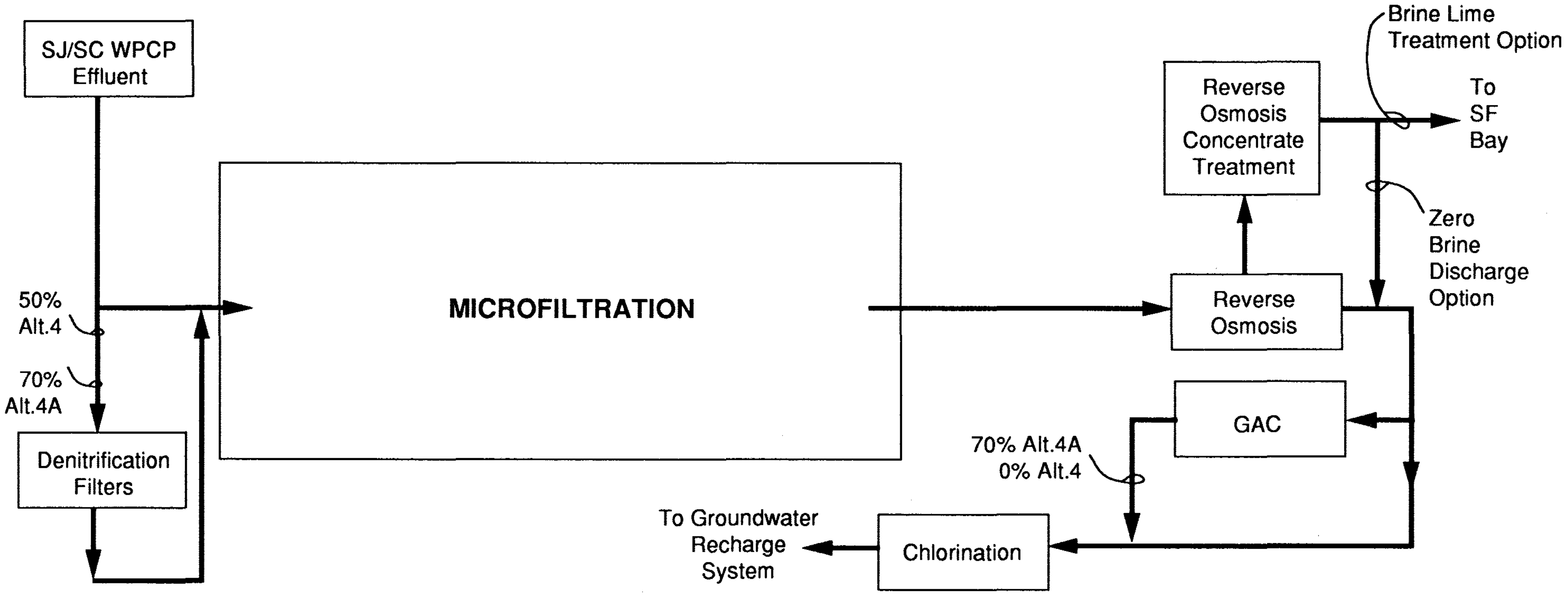
- Composite (Alt. 3)

  TDS - Groundwater Nondegradation
  NO3 - DOHS draft Groundwater Regulations
  TOC - Import/Percolation Pond Water Quality

VOLUME

- 20 mgd Product Water
- 25 mgd Influent - Brine Lime Treatment Option
  20 mgd Influent - Zero Brine Discharge Option

FIGURE 6-3
TREATMENT ALTERNATIVE 3



POSSIBLE TREATMENT STANDARDS

- Groundwater Nondegradation (Alt. 4A)
- Composite (Alt. 4)
  - TDS - Groundwater Nondegradation
  - NO3 - DOHS draft Groundwater Regulations
  - TOC - Import/Percolation Pond Water Quality

VOLUME

- 20 mgd Product Water
- 25 mgd Influent - Brine Lime Treatment Option
  20 mgd Influent - Zero Brine Discharge Option

FIGURE 6-4
TREATMENT ALTERNATIVE 4

RO brine is treated by either lime brine or zero brine discharge methods. With lime brine treatment, the effluent is discharged to San Francisco Bay using a new pipeline and outfall with diffuser. With zero brine discharge treatment, the effluent water quality matches the RO effluent water quality, and so both are blended together as RO product water. With lime brine treatment, 20 percent of the treated water is discharged as brine from the groundwater treatment plant. With zero brine discharge treatment, no brine is discharged so the groundwater treatment plant influent can be 20 percent less than the plant influent with lime brine treatment.

Important process design criteria and performance data to be determined during pilot testing include parameters such as: methanol, lime, soda, carbon dioxide, and coagulant chemical requirements; metals and TOC removal data by lime soda softening; sedimentation rates; maximum filtration rates and filter run lengths; RO membrane cleaning frequency and flux decline rate; GAC backwash and regeneration frequency; chlorine dose requirements and decay rates; disinfection by-products formed; and general loading rates and resulting performance data for all process units. Each wastewater is unique and thus there are many unknowns when projecting alternative costs and final water quality.

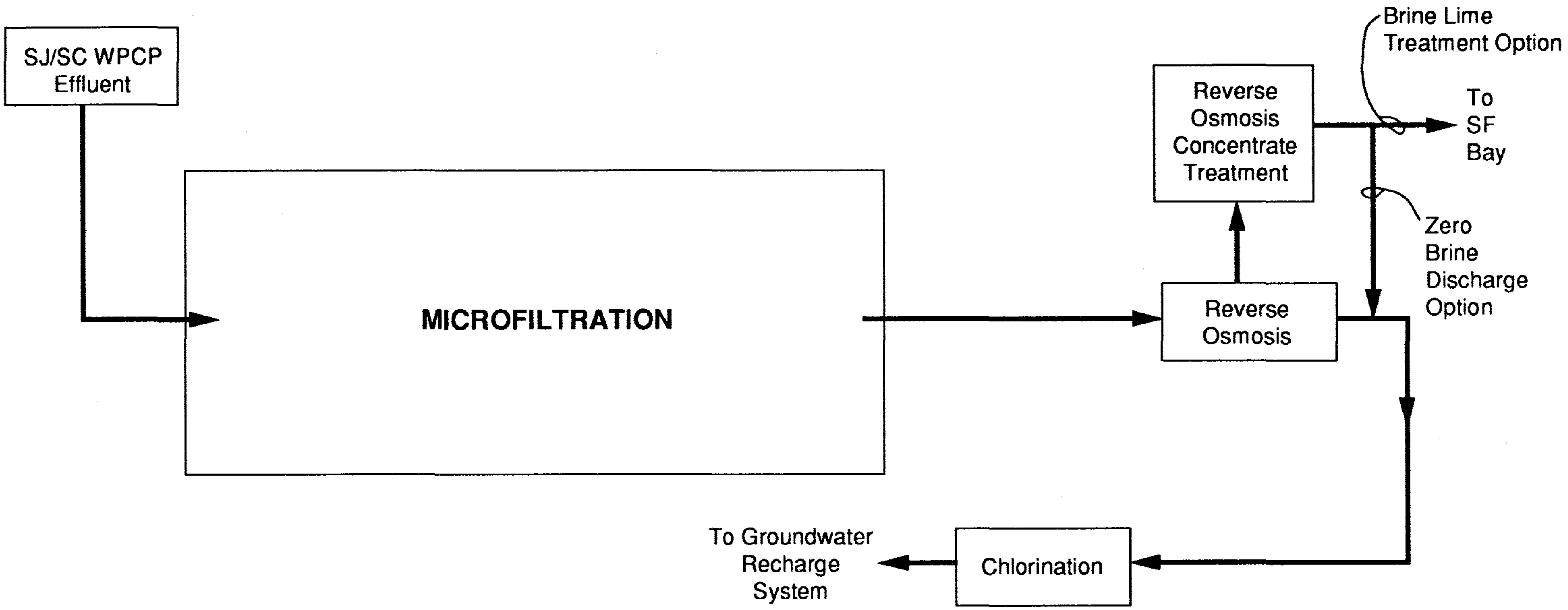
Treatment Alternative 5

Treatment Alternative 5, shown on Figure 6-5, is essentially Treatment Alternative 4 without the denitrification or GAC process units. This results in a water quality meeting the composite standards.

Treated Water Quality

Projected process efficiencies and final effluent water quality for each alternative are presented in Tables 6-3, 6-4, and 6-5. The removal percentages for lime soda softening are based on data from similar processes Water Factory 21, and must be confirmed on SJ/SC WPCP effluent during pilot testing.

Because TDS, nitrate, and TOC seem to be the controlling effluent quality parameters, Table 6-6 summarizes the TDS, nitrate, and TOC concentrations in the final effluent water for each alternative, along with the percent plant flow processed. The flow through the RO units in Alternative 2 was selected at 60 percent to meet the groundwater nondegradation TDS standard of 350 mg/l. Alternatives meeting the composite standard could have nitrate concentrations ranging from 3 to 10 mg/l. The flows through the denitrification filters in Alternatives 1, 2, and 4 were assumed at 50 and 70 percent of the total plant influent flow, intending to represent a range of effluent quality. These denitrification flow percentages can be adjusted to provide increased or decreased denitrification, with a corresponding increase or decrease in cost. Alternative 1A is projected to meet the groundwater nondegradation TOC standard of 1 mg/l using 100 percent flow through the RO units. Alternative 4A is


SJ/SC WPCP Effluent
MICROFILTRATION
Reverse Osmosis
Reverse Osmosis Concentrate Treatment
Brine Lime Treatment Option
To SF Bay
Zero Brine Discharge Option
Chlorination
To Groundwater Recharge System

POSSIBLE TREATMENT STANDARDS

- Composite (Alt. 5)

  TDS - Groundwater Nondegradation
  NO3 - DOHS draft Groundwater Regulations
  TOC - Import/Percolation Pond Water Quality

VOLUME

- 20 mgd Product Water
- 25 mgd Influent - Brine Lime Treatment Option
  20 mgd Influent - Zero Brine Discharge Option

FIGURE 6-5
TREATMENT ALTERNATIVE 5

Table 6-3
Projected Process Removal Percentages
SJ WPCP Effluent[a]

Parameter	Unit	Denite Filters	Lime/ Soda[c]	Filtration	RO[b]	Brine Lime/ Soda[c]	GAC	Micro-filtration
TDS	mg/l		0		93	10		
Nitrate as N	mg/l	[d]			65			
Arsenic	µg/l		0		37-88	24		
Cadmium	µg/l		32		87-95	32		
Chromium	µg/l		56		42-98	56		
Copper	µg/l		35		74-95	35		
Cyanide	µg/l		53		62-95	53		
Lead	µg/l		52		69-95	52		
Mercury	µg/l				79-95			
Nickel	µg/l		0		93-95	67		
Silver	µg/l		37		37-88	37		
Zinc	µg/l		26		78-95	26		
Selenium	µg/l							
Total Coliform	MPN		99	90	0	2.5		
Turbidity	NTU		90	80	0	1.5		
TOC	mg/l		50	0	90		50	30

[a] All removal percentages to be determined during pilot test. Projected removal percentages are based on SJ WPCP effluent concentration and assumed influent concentrations for each unit process within the treatment alternatives.

[b] Projected removal rates for cellulose acetate membranes. Lower range of removal rate based on limited Water Factory 21 data.

[c] Removal rates based on limited Water Factory 21 data.

[d] Nitrate removal in the denitrification filters is based on 2 mg/l nitrate as N in the denitrification filters.

Table 6-4
Final Reclamation Effluent Quality[a]
Composite Standards

Parameter	Unit	Treatment Alternative 1 Effluent	Treatment Alternative 2 Effluent	Treatment Alternative 3 Effluent	Treatment Alternative 4 Effluent	Treatment Alternative 5 Effluent	Groundwater Nondegradation Standard	Composite Standard
TDS	mg/l	61	385	61	61	61	350	350
Nitrate as N	mg/l	5.7	5.6	9.1	4.9	9.1	3.4	5.8/10
Arsenic	µg/l	3.2	3.9	3.2	3.2	3.2	--	--
Cadmium	µg/l	0.04	0.16	0.04	0.07	0.07	1 to 2	1 to 2
Chromium	µg/l	0.5	0.6	0.5	1.0	1.0	<1 to 5	<1 to 5
Copper	µg/l	1.5	3.3	1.5	2.3	2.3	<10 to 50	<10 to 50
Lead	µg/l	0.3	0.6	0.3	0.6	0.6	<10 to 30	<10 to 30
Mercury	µg/l	0.06	0.16	0.06	0.06	0.06	--	--
Nickel	µg/l	1.2	7.5	1.2	1.2	1.2	<10	<10
Silver	µg/l	1.6	2.0	1.6	2.6	2.6	<5	<5
Zinc	µg/l	12	30	12	17	17	<100	<100
Total Coliform	MPN	0.01	0.01	0.01	8.0	8.0	--	--
Turbidity	NTU	0.04	0.04	0.04	2.0	2.0	--	--
TOC	mg/l	1.0	2.5	1.0	1.6	1.6	1.0	1.6

[a] Water quality projections based on the treatment processes shown on Figures 6-1 through 6-5, the projected process removal percentages presented in Table 6-3, and the percent of plant flow processed as presented in Table 6-6.

Table 6-5
Final Reclamation Effluent Quality[a]
Groundwater Nondegradation Standard

Parameter	Unit	Treatment Alternative 1A Effluent	Treatment Alternative 4A Effluent	Groundwater Nondegradation Standard
TDS	mg/l	61	61	350
Nitrate as N	mg/l	3.2	3.2	3.4
Arsenic	µg/l	3.2	3.2	-
Cadmium	µg/l	0.04		1 to 2
Chromium	µg/l	0.5	0.07	<1 to 5
Copper	µg/l	1.5	1.0	<10 to 50
Lead	µg/l	0.3	2.3	<10 to 30
Mercury	µg/l	0.06	0.62	-
Nickel	µg/l	1.19	0.06 1.2	<10
Silver	µg/l	1.6	2.5	<5
Zinc	µg/l	12	17	<100
Total Coliform	MPN	0.01	8.0	-
Turbidity	NTU	0.04	2.0	-
TOC	mg/l	1.0	1.0	1.0

[a] Water quality projections based on the treatment processes shown on Figures 6-1 through 6-5, the projected process removal percentages presented in Table 6-3, and the percent of plant flow processed as presented in Table 6-6.

Table 6-6
Selected Water Quality and Process Data

Treatment Alternative	Treatment Standard	Product Water Quality			Percent Plant Flow Processed						
		TDS	NO_3 as N	TOC	Denitrification Filters	RO	GAC	Lime	Filtration	Microfiltation	Chlorination
1	Composite	61	5.7	1.0	40	Δ	0	Δ	Δ	0	Δ
2	Composite	385	5.6	2.5	70	60	40	Δ	Δ	0	Δ
3	Composite	61	9.1	1.0	0	Δ	0	Δ	Δ	0	Δ
4	Composite	61	4.9	1.6	50	Δ	0	0	0	Δ	Δ
5	Composite	61	9.1	1.6	0	Δ	0	0	0	Δ	Δ
1A	Nondegradation	61	3.2	1.0	70	Δ	0	Δ	Δ	0	Δ
4A	Nondegradation	61	3.2	1.0	70	Δ	70	0	0	Δ	Δ
Groundwater Nondegradation Standard		350	3.4	1.0							
Composite Standard											
20% Dilution		350	10	2.5							
50% Dilution		350	5.8	1.6							

Notes:
RO brine treatment method does not affect treatment plant product water quality.

- 0 Percent plant flow processed
Δ 100 Percent plant flow processed

projected to need 100 percent flow through the microfiltration units plus 70 percent flow through the GAC process to meet the groundwater nondegradation TOC standard.

Direct Injection Dilution Water Treatment

As discussed in Chapter 3, the reclaimed water will be diluted to a 50 percent blend with raw imported water before direct injection groundwater recharge. The imported dilution water will require coagulation and direct filtration to reduce the suspended solids to an acceptable level. The dilution water will also be chlorinated to maintain a chlorine residual in the conveyance piping and injection wells, preventing biological growths.

Plant Location Alternatives

Two treatment plant locations are currently under consideration. The first location would be near San Francisco Bay Zanker road site adjacent to SJ/SC WPCP, as identified in the Nonpotable Reclamation Facility Plan. This 32-acre site would contain both the nonpotable and the groundwater recharge treatment plants. A second general location has been identified in the unconfined aquifer or forebay region of the groundwater basin, somewhere central to the three percolations ponds, probably near the Guadalupe percolation area and the SCVWD headquarters. A minimum of 15 to 25 acres would be needed to locate the groundwater recharge treatment plant, depending on the final selected processes and percent treated in each process. A specific parcel of land has not been identified for the second location alternative and could be very difficult to locate, due to the area requirements and the general resistance in populated neighborhoods. The treatment alternative selection is independent of the treatment plant location. The cost of the treatment plant would be affected mainly by the cost of land (not included in these cost estimates) and the need for piles at the Zanker road site only. The cost of piles is not included in these estimates but will be developed during the next phase of work.

The advantages of the Zanker Road location are that the city already owns it and is planning on developing it for the nonpotable project, acquisition looks likely with little/no local opposition, and land is relatively less costly. The disadvantages are that it is more distant from SCVWD operations and personnel.

The possible advantages of the forebay plant location include:

- A small portion of the pipeline cost might be reduced by combining the nonpotable and potable pipelines in common areas. However, the cost savings is less than anticipated because the routing for the combined conveyance up Guadalupe Creek results in a total increase in groundwater recharge pipe length when compared to the alternative of separate routing up Coyote Creek.

- This location will provide more convenient access, because the groundwater recharge treatment plant will likely be operated by SCVWD.

The possible disadvantages of the forebay plant locations are:

- Land acquisition costs will be high in essentially all areas being considered for reclamation, but may be higher near the SCVWD offices.
- Pumping costs would be increased for the location near the SCVWD with the lime brine treatment option, because the recharge treatment plant influent is 20 percent greater than treatment plant effluent. Pumping costs would be similar for the zero brine discharge treatment option, because plant influent essentially equals plant effluent.
- Additional cost for brine conveyance to San Francisco Bay if the RO lime brine treatment is selected.
- There may be significant, nonyielding public opposition to locating a reclamation treatment plant in the forebay region where there is less separation from residential areas. Increased use of chemicals, truck traffic, noise, odors, and construction make it difficult to site a new treatment plant in/near residential neighborhoods.
- Environmental impacts are likely to be significant at most potential sites. As an example of the magnitude of impacts that may be encountered in locating satellite plants, the SCVWD has been unable to locate new recharge facilities in the forebay area where the recharge and reuse capacity exists. It would be difficult to locate a wastewater treatment and reclamation plant where a percolation pond cannot be located.

The dilution water treatment facilities, required only with the direct injection recharge alternative, would be located with the reclaimed water groundwater recharge treatment facilities. The 20-mgd reclaimed water would be blended 50 percent with the 20-mgd treated dilution water and then pumped to the direct injection wells.

Reclaimed Water Treatment Recommendations

Because of cost considerations and the effects of recharge water blending, it is recommended that the regulatory agencies and the SCVWD Board evaluate the acceptability of the recharge water quality meeting the composite standards versus the groundwater nondegradation standards. In this case, treatment Alternatives 1 or 3 would be recommended as the most tested and reliable option. However, we would recommend that treatment Alternatives 4 and 5 using microfiltration also be included in the pilot testing facility because of the potential for eliminating lime treatment and cost savings.

If the regulatory agencies, the SCVWD Board, and the City of San Jose decide that the recharge water quality should meet the groundwater nondegradation standards, then treatment Alternative 1A would be recommended as the most tested and reliable option. Again, we would recommend that treatment Alternative 4A using microfiltration also be included in the pilot-testing facility, because of the potential for cost savings and the elimination of lime treatment.

Order-of-Magnitude Cost Estimate

Capital, O&M, and total costs have been estimated for each of the five treatment alternatives described above. The accuracy of the cost estimates is order-of-magnitude. These costs are approximate estimates made without detailed engineering and site data, and are usually accurate with +50 to -35 percent.

The cost and exact configuration of each alternative vary depending upon the standard to which the water is being treated and the type of treatment the RO brine receives. Tables 6-7 through 6-12 present order-of-magnitude cost estimate information. Table 6-7 first summarizes all options, followed by four tables (6-8, 6-9, 6-10, and 6-11) presenting detailed cost breakdowns. The detailed breakdowns address the following treatment combinations:

- Composite standards, lime brine treatment
- Groundwater nondegradation standards, lime brine treatment
- Composite standards, zero brine discharge treatment
- Groundwater nondegradation standards, zero brine discharge treatment

The cost estimates have been prepared for comparison with other sources of water and other wastewater disposal options and are derived from the information available at the time of estimate preparation. This information includes manufacturers' estimates, published cost data, and scale-up and scale-down of costs from similar facilities. These cost estimates were first prepared in 1989 and have now been updated to reflect revised treatment processes and flowrates. The final costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, and other variable features. As a result, the final costs will vary from those presented in this report. Because of these factors, project feasibility, risks, and funding needs must be carefully reviewed before making specific financial decisions or establishing project budgets.

Table 6-12 presents a cost estimate for dilution water treatment. For a direct injection recharge alternative, these treatment costs are added to the reclaimed water treatment costs presented in Tables 6-8 through 6-11.

Table 6-7
SUMMARY OF ESTIMATED COSTS FOR TREATMENT ALTERNATIVES(a)

Treatment Alternative(b)	Flow Rate (mgd)		Capital Cost(c) ($1,000)	O&M Cost ($1,000)	Annualized Cost ($1,000)	Water Costs(d) ($/AF)
	Influent	Effluent				
LB-1	25	20	$103,078	$19,058	$30,249	$1,350
LB-2	23	20	$98,121	$16,511	$27,164	$1,212
LB-3	25	20	$90,702	$17,726	$27,573	$1,231
LB-4	25	20	$91,704	$19,694	$29,650	$1,323
LB-5	25	20	$78,482	$18,271	$26,791	$1,196
ZD-1	20	20	$103,349	$25,300	$36,521	$1,630
ZD-2	20	20	$94,500	$19,769	$30,029	$1,340
ZD-3	20	20	$93,300	$24,218	$34,348	$1,533
ZD-4	20	20	$94,102	$25,793	$36,009	$1,607
ZD-5	20	20	$83,524	$24,654	$33,723	$1,505
LB-1A	25	20	$108,554	$19,923	$31,709	$1,415
LB-4A	25	20	$114,069	$22,399	$34,784	$1,553
ZD-1A	20	20	$107,545	$25,972	$37,648	$1,680
ZD-4A	20	20	$117,168	$28,544	$41,265	$1,842

(a) All estimated costs are in 1992 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.

(b) Treatment alternatives are shown schematically in Figures 6-1 through 6-5. Treatment Alternatives 1,2,3,4, and 5 meet the composite standards. Treatment Alternatives 1A and 4A meet the groundwater nondegradation standards.

Brine Disposal Options: LB = lime brine treatment, ZD = zero brine discharge treatment

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

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Table 6-8
BREAKDOWN OF ESTIMATED COSTS FOR TREATMENT ALTERNATIVES
COMPOSITE STANDARDS,
BRINE LIME TREATMENT(a)

Treatment Alternative(b)	Flow Rate (mgd)	Capital Cost(c) ($1,000)	O&M Cost ($1,000)	Annualized Cost ($1,000)	Water Costs(d) ($/AF)
Alternative LB-1 Influent	25				
Denitrification		$12,376	$1,332	$2,676	$119
Lime/Soda Softening		$24,592	$3,542	$6,212	$277
Filtration		$8,298	$669	$1,570	$70
Sludge Handling		$9,108	$3,036	$4,025	$180
Reverse Osmosis		$38,096	$7,926	$12,062	$538
Chlorination		$2,613	$259	$543	$24
Brine Lime Treatment		$7,995	$2,293	$3,161	$141
Effluent	20				
TOTAL		$103,078	$19,058	$30,249	$1,350
Alternative LB-2 Influent	23				
Denitrification		$18,129	$2,231	$4,200	$187
Lime/Soda Softening		$22,624	$3,259	$5,715	$255
Filtration		$7,635	$616	$1,445	$64
Sludge Handling		$8,379	$2,793	$3,703	$165
Reverse Osmosis		$22,858	$4,756	$7,237	$323
Granular Activated Carbon		$11,085	$1,221	$2,424	$108
Chlorination		$2,613	$259	$543	$24
Brine Lime Treatment		$4,797	$1,376	$1,896	$85
Effluent	20				
TOTAL		$98,121	$16,511	$27,164	$1,212
Alternative LB-3 Influent	25				
Lime/Soda Softening		$24,592	$3,542	$6,212	$277
Filtration		$8,298	$669	$1,570	$70
Sludge Handling		$9,108	$3,036	$4,025	$180
Reverse Osmosis		$38,096	$7,926	$12,062	$538
Chlorination		$2,613	$259	$543	$24
Brine Lime Treatment		$7,995	$2,293	$3,161	$141
Effluent	20				
TOTAL		$90,702	$17,726	$27,573	$1,231
Alternative LB-4 Influent	25				
Denitrification		$13,222	$1,423	$2,859	$128
Microfiltration		$29,778	$7,792	$11,025	$492
Reverse Osmosis		$38,096	$7,926	$12,062	$538
Chlorination		$2,613	$259	$543	$24
Brine Lime Treatment		$7,995	$2,293	$3,161	$141
Effluent	20				
TOTAL		$91,704	$19,694	$29,650	$1,323
Alternative LB-5 Influent	25				
Microfiltration		$29,778	$7,792	$11,025	$492
Reverse Osmosis		$38,096	$7,926	$12,062	$538
Chlorination		$2,613	$259	$543	$24
Brine Lime Treatment		$7,995	$2,293	$3,161	$141
Effluent	20				
TOTAL		$78,482	$18,271	$26,791	$1,196

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.

(b) Treatment alternatives are shown schematically in Figures 6-1 through 6-5.
LB Lime Brine Reverse Osmosis Brine Treatment

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

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Table 6-9
BREAKDOWN OF ESTIMATED COSTS FOR TREATMENT ALTERNATIVES COMPOSITE STANDARDS, ZERO DISCHARGE BRINE TREATMENT(a)

Treatment Alternative(b)	Flow Rate (mgd)	Capital Cost(c) ($1,000)	O&M Cost ($1,000)	Annualized Cost ($1,000)	Water Costs(d) ($/AF)
Alternative ZD-1 Influent	20				
Denitrification		$10,049	$1,082	$2,173	$97
Lime/Soda Softening		$19,673	$2,834	$4,970	$222
Filtration		$6,639	$536	$1,256	$56
Sludge Handling		$7,286	$2,429	$3,220	$144
Reverse Osmosis		$30,477	$6,341	$9,650	$431
Chlorination		$2,613	$259	$543	$24
Zero Brine Discharge		$26,612	$11,820	$14,709	$657
Effluent	20				
TOTAL		$103,349	$25,300	$36,521	$1,630
Alternative ZD-2 Influent	20				
Denitrification		$12,950	$1,594	$3,000	$134
Lime/Soda Softening		$19,673	$2,834	$4,970	$222
Filtration		$6,639	$536	$1,256	$56
Sludge Handling		$7,286	$2,429	$3,220	$144
Reverse Osmosis		$18,286	$3,804	$5,790	$258
Granular Activated Carbon		$11,085	$1,221	$2,424	$108
Chlorination		$2,613	$259	$543	$24
Zero Brine Discharge		$15,967	$7,092	$8,826	$394
Effluent	20				
TOTAL		$94,500	$19,769	$30,029	$1,340
Alternative ZD-3 Influent	20				
Lime/Soda Softening		$19,673	$2,834	$4,970	$222
Filtration		$6,639	$536	$1,256	$56
Sludge Handling		$7,286	$2,429	$3,220	$144
Reverse Osmosis		$30,477	$6,341	$9,650	$431
Chlorination		$2,613	$259	$543	$24
Zero Brine Discharge		$26,612	$11,820	$14,709	$657
Effluent	20				
TOTAL		$93,300	$24,218	$34,348	$1,533
Alternative ZD-4 Influent	20				
Denitrification		$10,577	$1,139	$2,287	$102
Microfiltration		$23,822	$6,234	$8,820	$394
Reverse Osmosis		$30,477	$6,341	$9,650	$431
Chlorination		$2,613	$259	$543	$24
Zero Brine Discharge		$26,612	$11,820	$14,709	$657
Effluent	20				
TOTAL		$94,102	$25,793	$36,009	$1,607
Alternative ZD-5 Influent	20				
Microfiltration		$23,822	$6,234	$8,820	$394
Reverse Osmosis		$30,477	$6,341	$9,650	$431
Chlorination		$2,613	$259	$543	$24
Zero Brine Discharge		$26,612	$11,820	$14,709	$657
Effluent	20				
TOTAL		$83,524	$24,654	$33,723	$1,505

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.

(b) Treatment alternatives are shown schematically in Figures 6-1 through 6-5.
ZD Zero Discharge Brine Treatment

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

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Table 6-10
BREAKDOWN OF ESTIMATED COSTS FOR TREATMENT ALTERNATIVES NONDEGRADATION STANDARDS, BRINE LIME TREATMENT

Treatment Alternative(b)	Flow Rate (mgd)	Capital Cost(c) ($1,000)	O&M Cost ($1,000)	Annualized Cost ($1,000)	Water Costs(d) ($/AF)
Alternative LB-1A Influent	25				
Denitrification		$17,852	$2,197	$4,135	$185
Lime/Soda Softening		$24,592	$3,542	$6,212	$277
Filtration		$8,298	$669	$1,570	$70
Sludge Handling		$9,108	$3,036	$4,025	$180
Reverse Osmosis		$38,096	$7,926	$12,062	$538
Chlorination		$2,613	$259	$543	$24
Brine Lime Treatment		$7,995	$2,293	$3,161	$141
Effluent	20				
TOTAL		$108,554	$19,923	$31,709	$1,415
Alternative LB-4A Influent	25				
Denitrification		$18,510	$1,992	$4,002	$179
Microfiltration		$29,778	$7,792	$11,025	$492
Reverse Osmosis		$38,096	$7,926	$12,062	$538
Granular Activated Carbon		$19,400	$2,137	$4,243	$189
Chlorination		$2,613	$259	$543	$24
Brine Lime Treatment		$7,995	$2,293	$3,161	$141
Effluent	20				
TOTAL		$116,392	$22,399	$35,036	$1,564

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.

(b) Treatment alternatives are shown schematically in Figures 6-1 through 6-5.
LB Lime Brine Reverse Osmosis Brine Treatment

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

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Table 6-11
BREAKDOWN OF ESTIMATED COSTS FOR TREATMENT ALTERNATIVES NONDEGRADATION STANDARDS, ZERO DISCHARGE BRINE TREATMENT(a)

Treatment Alternative(b)	Flow Rate (mgd)	Capital Cost(c) ($1,000)	O&M Cost ($1,000)	Annualized Cost ($1,000)	Water Costs(d) ($/AF)
Alternative ZD-1A Influent	20				
Denitrification		$14,245	$1,753	$3,300	$147
Lime/Soda Softening		$19,673	$2,834	$4,970	$222
Filtration		$6,639	$536	$1,256	$56
Sludge Handling		$7,286	$2,429	$3,220	$144
Reverse Osmosis		$30,477	$6,341	$9,650	$431
Chlorination		$2,613	$259	$543	$24
Zero Brine Discharge		$26,612	$11,820	$14,709	$657
Effluent	20				
TOTAL		$107,545	$25,972	$37,648	$1,680
Alternative ZD-4A Influent	20				
Denitrification		$14,245	$1,753	$3,300	$147
Microfiltration		$23,822	$6,234	$8,820	$394
Reverse Osmosis		$30,477	$6,341	$9,650	$431
Granular Activated Carbon		$19,400	$2,137	$4,243	$189
Chlorination		$2,613	$259	$543	$24
Zero Brine Discharge		$26,612	$11,820	$14,709	$657
Effluent	20				
TOTAL		$117,168	$28,544	$41,265	$1,842

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.

(b) Treatment alternatives are shown schematically in Figures 6-1 through 6-5.
ZD Zero Discharge Brine Treatment

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

Table 6-12
BREAKDOWN OF ESTIMATED COSTS DILUTION WATER TREATMENT(a) PROJECT ALTERNATIVE 4

Treatment	Flow Rate (mgd)	Capital Cost(b) ($1,000)	O&M Cost ($1,000)	Annualized Cost(a) ($1,000)	Water Costs(c) ($/AF)
DILUTION TREATMENT (ALT 4)	20.0				
COAGULATION		$541	$582	$641	$29
FILTRATION		$6,639	$536	$1,256	$56
SLUDGE HANDLING		$7,286	$2,429	$3,220	$144
CHLORINATION		$2,613	$259	$543	$24
EFFLUENT	20.0				
TOTAL		$17,080	$3,806	$5,660	$253

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.

(b) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(c) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

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The following is a summary of the basis of the cost estimates and the major assumptions:

- All costs are in 1992 dollars. The midpoint of construction is estimated at 1999. Assuming 5 percent inflation, all cost estimates can be escalated to 1995 dollars by using a factor of 1.44.
- Capital costs are derived primarily from scale-up and scale-down of costs from similar existing facilities and from published cost curve information. Costs include allowances for site work, electrical, and support facilities; construction contingencies; and administration, engineering, and legal costs. Costs for piles are not included but will be developed during the next phase of work.
- Annual O&M costs include the costs for labor, power, chemicals and supplies, and equipment repair. Power costs are assumed at $0.071 per kW-hr.
- Total unit costs of reclaimed water produced are estimated based on a discount rate of 8-7/8 percent and a discount period of 20 years.

Blue Ribbon Committee Comments

Both Dr. Bull and Mr. Lauer generally concurred with the overall project approach, underscoring the need for pilot testing to determine treatment and water quality issues.

Mr. Lauer recommended additional treatment considerations, such as higher percentage recovery RO to decrease the brine volume, adding or operating a Biological Activated Carbon (BAC) process, and adding air stripping on the RO effluent.

Chapter 7
Treatment Residuals

Chapter 7
Treatment Residuals

Purpose

The purpose of this chapter is to review and refine the handling options for the following waste residuals that may potentially be generated from a future groundwater recharge reclamation plant:

- RO brine
- Lime sludge
- Spent GAC
- Filter and carbon adsorber backwash wastewater

This chapter reviews and updates the treatment residuals portion of the Reconnaissance Report. It also addresses the regulatory acceptance of waste residual handling methods. Each of the waste streams are discussed in the following sections. All waste residuals would be handled at the groundwater recharge treatment plant and would not be returned to SJ/SC WPCP. Brine and backwash water would not be returned to SJ/SC WPCP because of the metal concentrations exceeding those allowed by the NPDES permit. The lime sludge and spent GAC would not be returned because SJ/SC WPCP does not have sludge dewatering or carbon regeneration facilities.

Reverse Osmosis Brine

This section presents a summary of the RO brine handling methods suggested in the Reconnaissance Report and refined alternatives based on information derived from the SJ/SC WPCP In-Plant Metals Removal Study, October 1989, prepared by CH2M HILL for the City of San Jose; other studies performed by CH2M HILL; and discussion with CH2M HILL regulatory and technical experts.

Reconnaissance Report Review

Based on the Reconnaissance Report, the following two methods were offered for handling RO brine:

1. Conveyance and discharge to the Bay via a possible future deep water outfall.

2. Chemical precipitation of the metals in the RO brine and return of the treated brine to the SJ/SC WPCP effluent discharge.

Because the SJ/SC WPCP discharge is regulated by an NPDES permit with very stringent metals limits, brine will not be returned to the SJ/SC WPCP effluent.

Alternative Refinement

The Basin Plan lists effluent limitations for toxic substances, depending on whether the receiving body is a freshwater or marine environment and whether the water is shallow or deep. A minimum initial dilution of 10:1 is necessary to be considered a deep-water discharge. Dischargers that discharge into relatively low salinity marine waters, such as SJ/SC WPCP, must meet the lower of the marine or freshwater effluent limitations.

For the purposes of comparing costs associated with various levels of brine treatment, we will present alternatives that discharge brine to the Bay using a new outfall with a 10:1 dilution diffuser. At 10:1 dilution, all metal concentrations would be in compliance with the Basin Plan except mercury. RWQCB's acceptance of a proposed mercury site specific limits would bring mercury into compliance. Even if the brine did not exceed the metals concentrations listed in the proposed California Enclosed Bay/Estuary Plan, it is still unlikely that a new outfall would be permitted without strong environmental and regulatory reclamation support. If a new NPDES permit is applied for, bioassays will be required. While the survival rate in pH adjusted, lime treated brine is expected to be somewhat less than that of SJ/SC WPCP's bioassay, it is anticipated that bioassays can be successfully operated. Pilot testing will be required to confirm these assumptions.

Based on discussions with CH2M HILL technical experts, the following RO brine handling alternatives will be further evaluated:

- Return of untreated RO brine to the San Francisco Bay using an independent outfall

- Lime Brine Treatment: Lime treatment of the RO brine with lime sludge dewatering and land disposal with treated brine discharged to the Bay using an independent outfall

- Zero Brine Discharge Treatment: Lime treatment, filtration, and RO processing of the RO brine. This RO step would use RO membranes similar to those used when desalting seawater, and this will be referred to here as "Seawater RO." Seawater RO permeate would be blended with the main process stream RO permeate for groundwater recharge. Reject brine from the seawater RO process would be further concentrated through vapor compression evaporation and forced circulation crystallization to produce a crystalline solid for encapsulation and land disposal. This is a zero discharge option.

Figure 7-1 presents a process flow schematic of the alternative brine handling methods.

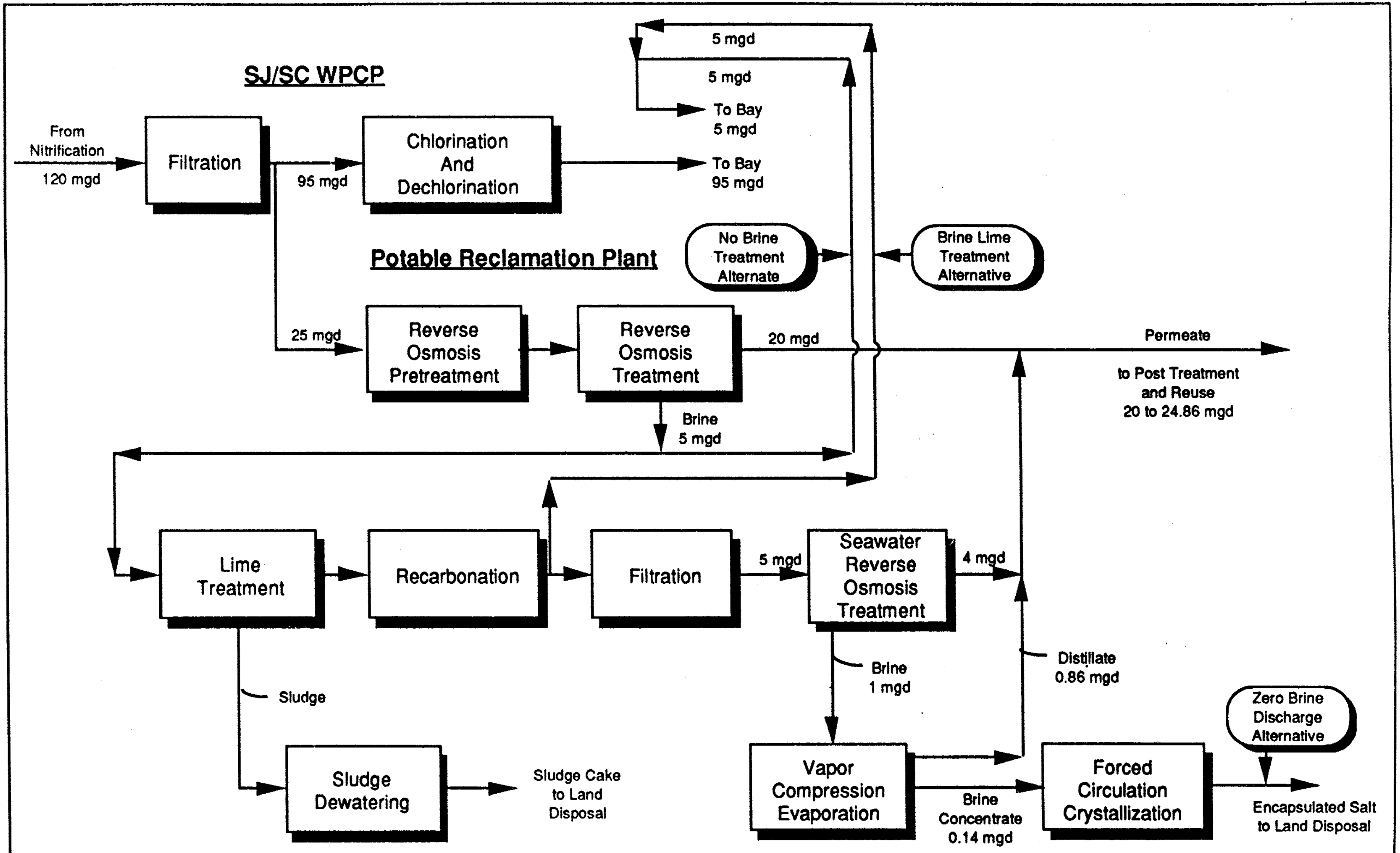

SJ/SC WPCP
From Nitrification
120 mgd
Filtration
95 mgd
Chlorination And Dechlorination
To Bay 95 mgd
5 mgd
5 mgd
To Bay 5 mgd
Potable Reclamation Plant
No Brine Treatment Alternate
Brine Lime Treatment Alternative
25 mgd
Reverse Osmosis Pretreatment
Reverse Osmosis Treatment
20 mgd
Permeate
to Post Treatment and Reuse 20 to 24.86 mgd
Brine 5 mgd
Lime Treatment
Recarbonation
Filtration
5 mgd
Seawater Reverse Osmosis Treatment
4 mgd
Sludge
Sludge Dewatering
Sludge Cake to Land Disposal
Brine 1 mgd
Distillate 0.86 mgd
Vapor Compression Evaporation
Brine Concentrate 0.14 mgd
Forced Circulation Crystallization
Zero Brine Discharge Alternative
Encapsulated Salt to Land Disposal

FIGURE 7-1
RO BRINE HANDLING
ALTERNATIVES

Metals Reduction

Since reduction of metals loading to the Bay is one of the primary motivations for water reuse, the following analysis will project the metals mass loading reduction associated with each of the brine handling methods. The forthcoming metals reduction projections are based on:

- 1991 average SJ/SC WPCP effluent quality data
- An annual average SJ/SC WPCP flow of 120 mgd
- OCWD Water Factor 21 treatment performance data

Table 7-1 presents a summary of these basic criteria.

Table 7-1
SJ/SC WPCP Effluent Quality and Water Factory 21 Treatment Performance Data

	SJ/SC WPCP Effluent 1991 Average		Water Factory 21 Lime Treatment Performance 1989			Water Factor 21 RO Performance 1988-1989		
Metal	**µg/l**	**lb/d @ 120 mgd**	**Detection Limit, µg/l**	**Infl. Conc. Range, µg/l**	**Average % Removal**	**Detection Limit, µg/l**	**Infl. Conc. Range, µg/l**	**Average % Removal**
As	<2	<2	5.0	5.0-8.8	24	5.0	5.5-60	37
Cd	<0.5	<0.5	0.1	0.9-6.3	32	0.1	0.3-6.8	87
Cr	1.1	1.1	1.0	1.8-10.0	56	1.0	1.2-3.5	42
Cu	7	7	1.0	6.1-31.0	35	1.0	2.0-23.0	74
CN	14	14	0.1	5.2-110.0	53	0.1	0.5-49.0	62
Pb	<1	<1	1.0	1.1-38.0	52	1.0	2.2-5.8	69
Hg	<0.2	<0.2	0.5	<0.5	—	0.5	1.6-4.2	79
Ni	13	13	0.1	67.0-88.0	67	0.1	20.0-30.0	93
Ag	3	3	0.1	0.2-2.0	37	0.1	0.2-4.6	37
Zn	53	3	50.0	54-90	26	50.0	<50.0-230.0	78
Total		94.8						

Using the criteria presented in Table 7-1 and the flow rates depicted on Figure 7-1, Table 7-2 presents the estimated metals mass loading reduction to San Francisco Bay associated with each of the brine handling alternatives. The estimates presented in Table 7-2 are based on the following additional assumptions:

- The no brine treatment alternative possesses metals mass loading reduction potential because of assumed lime treatment preceding RO as well as metals not removed through the RO process itself.

Table 7-2 Brine Handling Alternatives Estimated Metals Mass Loading Reduction to San Francisco Bay			
Metal	**No Brine Treatment Mass Loading Reduction (lb/d)**	**Brine Lime Treatment Mass Loading Reduction[a] (lb/d)**	**Zero Brine Discharge Mass Loading Reduction[b] (lb/d)**
As	0.3	0.3	0.4
Cd	0.02	0.05	0.1
Cr	0.2	0.2	0.2
Cu	0.7	1.0	1.5
CN	2.0	2.5	2.9
Pb	0.2	0.2	0.2
Hg	0.03	0.03	0.04
Ni	2.2	2.2	2.7
Ag	0.4	0.5	0.6
Zn	2.0	4.4	11.1
Total	8.05	11.40	19.74

[a] Based on treating 25 mgd of SJ/SC WPCP effluent and returning 5-mgd lime treated brine to San Francisco Bay.

[b] Based on treating 20 mgd of SJ/SC WPCP effluent, without returning any flow to San Francisco Bay.

- In cases where the SJ/SC WPCP effluent concentration was less than the Water Factory 21 range reported in Table 7-1, a zero percent removal was assumed.

- In cases where the SJ/SC WPCP effluent concentration was greater than the Water Factory 21 range reported in Table 7-1, the average percent removal was assumed.

- The lime treatment process removal efficiencies reported in Table 7-1 were applied to both the SJ/SC WPCP effluent and the RO brine. Because of the higher ionic strength of the brine relative to the secondary effluent, it is possible that the brine lime treatment mass loading reduction is over estimated.

- The RO product water recovery rate was assumed to be 80 percent.

- In cases where the SJ/SC WPCP effluent metals concentration was below detection limits, the detection limit concentration was assumed.

The data presented in Table 7-2 are only projections to show the relative efficacy of the alternative brine handling methods in terms of metals loading reduction to the San Francisco Bay. Table 7-3 lists typical RO brine concentrations, along with typical RO lime brine treated effluent concentrations. As already stated, these concentrations exceed those allowed. Additional brine treatment alternatives will be considered under Task 3 work to refine process selection. Demonstration of the selected alternative will be required to verify actual performance.

Table 7-3
Typical Brine Concentrations

Metal	Units	Typical RO Brine Concentration	Typical Lime Brine Treated Effluent Concentration	Deep Water Basin Plan Limits[a]	
				Fresh Water	Marine Water
As	μg/l	9.3	7	50	360
Cd	μg/l	1.5	1	10.7	92
Cr	μg/l	1.7	0.7	110	500
Cu	μg/l	21.6	14	78	17
Pb	μg/l	3.3	1.6	23	53
g	μg/l	1.2	1.2	0.08	0.21
Ni	μg/l	79.1	26	1,570	65
Ag	μg/l	4.7	3	40	23
Zn	μg/l	219	160	1,055	840
TOC	mg/l	43	43	--	--
TDS	mg/l	4,046	3,641	--	--
Nitrates	mg/l	30	53	--	--

[a] Based on deep water effluent limits (10:1 dilution) per proposed Basin Plan amendments adopted on December 11, 1991.

[b] Per the California Enclosed Bays and Estuaries Plan, April 1991, Water Resources Control Board State of California, Table 1, Water Quality Objectives for Protection of Saltwater Aquatic Life; and Table 2, Water Quality Objectives for Enclosed Bays and Estuaries for Protection of Human Health, as adopted by The RWQCB December 11, 1991.

Based on the metals loading reduction analysis, groundwater recharge reclamation at the proposed scale of 20 to 25 mgd could contribute to the positive reduction of metals loading to the Bay. However, untreated brine and lime-treated brine would not meet the challenge as presented by the proposed NPDES permit limits.

Cost Opinions

Table 7-4 presents relative order-of-magnitude cost opinions for three brine handling alternatives. Only the relative cost differences are presented for the three alternatives, not the total cost of each alternative. Costs associated with land, brine return to the SJ/SC WPCP effluent, and hauling of residual solids offsite are not included. These cost opinions are intended to reflect the incremental cost increase associated with increasing brine treatment. The relative cost differences presented are generally within an accuracy range of plus 50 percent to minus 30 percent for this type of estimate. The baseline costs, excluding land costs, are included in Chapter 6, Treatment, cost estimates.

Table 7-4
Brine Handling Alternatives Relative Cost Comparison Opinions

Alternative	Relative Capital Cost (millions $)	Relative Annual O&M Cost (million $)	Relative Unit Cost[a] ($ per thousand gallons)
No Brine Treatment	0	0	0
Brine Lime Treatment	7.9	2.0	2.30
Zero Brine Discharge	17.7	20.6	13.75

[a] Unit cost based on a discount rate of 8-7/8 percent, a discount period of 20 years, 1992 dollars, and a brine generation rate of 5 mgd.

The cost opinions present in Table 7-4 show that the costs to treat the brine are substantial, particularly in light of the incremental total metals mass loading reductions available as presented in Table 7-2.

Recommendations

The no brine treatment alternative would certainly be the most economical solution. Although the metals mass loading reduction would not fulfill the proposed loading limits, this alternative would contribute to positive reduction of metals discharge to the Bay, would not further alleged degradation of the receiving saltwater marsh ecosystem, and would allow development of a new water supply that would help alleviate demand on the area's aquifer. However, this alternative would almost certainly be unacceptable to the regulatory agencies.

In lieu of achieving acceptance of the no brine treatment alternative, the brine lime treatment alternative would be the next most economically attractive alternative. This alternative, however, would only offer an estimated additional 3.4 pounds per day of metals reduction above that of the no brine treatment alternative, and the additional estimated expense would be substantial. With a 10:1 outfall dilution diffuser, all metals would be in compliance except mercury. The site-specific work may provide an adjusted mercury limit, putting the mercury in compliance and making this an acceptable option from a regulatory point of view. If this alternative could be negotiated to an acceptable outcome from a regulatory and institutional perspective, this would be the recommended brine disposal approach. This alternative would require demonstration to verify performance and establish design criteria.

The zero brine discharge alternative is the most costly alternative, especially considering the incremental metals mass loading reduction available. The zero brine discharge alternative has the advantage that it does not further add metals to the Bay that exceed anticipated NPDES concentration limits and that it does assure complete disposal of the brine residuals. The zero brine discharge alternative may be the only treatment option acceptable to the regulatory agencies.

Lime Sludge

This section presents a summary of the lime sludge handling methods suggested in the Reconnaissance Report and refined alternatives based on (1) information derived from the SJ/SC WPCP In-Plant Metals Removal Study, October 1989, prepared by CH2M HILL for the City of San Jose; and (2) information derived from a recent preliminary design report prepared by CH2M HILL for the West Basin Municipal Water District.

Reconnaissance Report Review

Based on the Reconnaissance Report the following two lime sludge disposal methods were offered:

1. Thickening, belt press dewatering, and landfill disposal
2. Thickening, plate and frame press dewatering, and landfill disposal

Lime recalcination was properly deleted from the available lime sludge handling alternatives because of the high energy requirements and the accumulation of metals in the recalcined lime that would hinder metals removal performance.

Alternative Refinement

Belt press versus plate and frame press dewatering was recently evaluated for the West Basin Municipal Water District water reclamation plant preliminary design. Following is a brief summary of the evaluation:

- Plate and frame presses have a proven operating history on lime sludge. Belt presses, however, have very limited full-scale operating history.
- Belt presses require continuous washwater for cleaning the belts, resulting in significantly higher recycle flow volume than for a plate and frame press. Therefore, the loading rate for belt presses is lower than that for plate and frame presses.

- The plate and frame press produces fewer wet tons of solids, and the drier sludge cake would be more acceptable as a landfill material. Plate and frame presses can produce a sludge cake in excess of 50 percent solids, while belt presses can produce a sludge cake containing about 30 percent solids.

- The higher cake solids content from the plate and frame press reduces the hauling and disposal costs relative to the belt press-generated cake.

- Although the equipment required for the plate and frame dewatering is about 30 percent more expensive than that required for belt press dewatering, the savings in chemical conditioning and the reduced sludge tonnage make plate and frame dewatering about 30 percent less expensive than belt press dewatering on a present worth basis.

Recommendation

Based on the previous points, plate and frame dewatering is recommended for lime sludge handling.

Spent GAC

This section presents a summary of the spent GAC handling methods presented in the Reconnaissance Report and refined alternatives based on discussions with CH2M HILL technical experts.

Reconnaissance Report Review

The Reconnaissance Report suggested onsite carbon regeneration with offgas after burning and scrubbing.

Alternative Refinement

Preliminary discussions with the California Department of Health Services indicate that an onsite regeneration facility could theoretically be permitted through the Bay Area Air Quality Management District (BAAQMD). The City of San Jose, however, would have to show that substantial effort was being expended to reduce the source of organics to the GAC adsorbers. This would involve further expansion of the SJ/SC WPCP industrial pretreatment program to further limit discharge of solvents to the municipal sewer system. In addition, local land use and environmental activists would likely criticize and possibly impede implementation of onsite carbon regeneration. Nevertheless, opposition may likely be persuaded to accept onsite regeneration if the benefits and costs of potable reuse were presented in comparison to other wastewater effluent disposal and water supply development alternatives.

The other option for spent GAC is offsite regeneration. The closest carbon regeneration facility is operated by Cameron Carbon, Inc., in Yakima, Washington. Discussions with Cameron Carbon, Inc. and with Erickson Trucking near San Jose were held to gather unit cost data for comparison to onsite regeneration costs.

Table 7-5 presents comparative order-of-magnitude cost estimates for onsite versus offsite carbon regeneration. These costs are preliminary and should not be used for financial decisionmaking. These costs do not include land or costs associated with disposal of GAC lost to attrition during the regeneration process. The carbon requiring regeneration was based on the following assumptions and criteria:

- Forty percent of the 20-mgd flow passes through GAC.
- Empty bed contact time is 30 minutes.
- Carbon bulk density is 28 lb/cubic foot.
- All carbon is regenerated 3 times per year with 10 percent loss from attrition each regeneration cycle.

Table 7-5
Spent GAC Handling Alternatives
Cost Comparison Opinions

Alternative	Capital Cost (million $)	Annual O&M Cost (million $)	Present Worth[a] (million $)
Onsite regeneration	1.24	0.48	0.62
Offsite regeneration	0	1.50	1.50

[a] Present worth based on a discount rate of 8-7/8 percent and a discount period of 20 years.

The cost opinions presented in Table 7-5 show that onsite regeneration is clearly more economical than offsite regeneration. These costs will be adjusted for the actual GAC flow rates associated with each of the treatment alternatives.

Recommendation

Because of economics, onsite regeneration is recommended. If, however, the regulatory and institutional constraints become too cumbersome and expensive to combat, then offsite regeneration becomes the default position. Because it is likely that permitting will be difficult/impossible, the offsite regeneration costs are used for the cost estimate.

Backwash Wastewater

This section presents the backwash wastewater handling method suggested in the Reconnaissance Report and reevaluation herein.

Reconnaissance Report Review

The Reconnaissance Report suggested the following backwash wastewater handling method:

- Washwater delivery to a settling basin with supernatant recycle to the reclamation plant influent and settled solids discharge to a sludge handling facility.

Alternative Refinement

Based on recent preliminary design of the West Basin Water Reclamation Plant, the following options are recommended depending on the RO pretreatment selected:

- Lime Pretreatment—equalize the backwash wastewater flow and recycle liquid and solids to the influent of the lime clarifiers.
- Microfiltration Pretreatment—equalize the backwash wastewater flow, treat with lime and filtration, then recycle treated effluent back to the influent of the lime clarifiers.

Conclusion

The recommended waste residual handling methods should be investigated further from an institutional and regulatory acceptance perspective to gain required support for groundwater recharge reclamation and the associated environmental and water supply benefits.

Blue Ribbon Committee Comments

Mr. Lauer commented that the RO brine residual in the Denver reclamation project was treated in a manner similar to the zero discharge treatment presented for this project.

Mr. Lauer suggested that a higher RO recovery be economically evaluated, now that zero discharge cost estimates are available.

Both Mr. Lauer and Dr. Bull thought that, given the South Bay discharge limitations, a zero discharge treatment was probably going to be the most viable option.

Chapter 8
Conveyance Systems

Chapter 8
Conveyance Systems

The conveyance system will link the groundwater recharge treatment plant with the existing Los Gatos, Guadalupe, and Coyote Creek recharge systems or with a series of direct injection wells. The location of the existing recharge systems are fixed. Therefore, the configuration of the conveyance system alternatives is dependent on the location of the groundwater recharge treatment plant and locations of injection wells. One direct injection well field has been tentatively located for the purposes of evaluating DOHS criteria and developing conveyance cost estimates.

For each conveyance alternative there are two options for treatment of reverse osmosis brine reject. One option is zero brine discharge, which does not affect conveyance system configuration. The other option involves lime treatment of brine reject and disposal into the San Francisco Bay and would require a pipeline and outfall from the groundwater recharge treatment plant to the San Francisco Bay.

Four conveyance/groundwater recharge treatment plant location alternatives were evaluated as follows:

- Alternative 1—Groundwater recharge treatment plant location would be near the SJ/SC WPCP. The conveyance system consists of a 58,000-foot trunk line that branches to each of the three recharge system ponds. The total length of the three branches is approximately 126,000 feet. The conveyance system follows existing SCVWD flood control right-of-way and is shown on Figure 8-1. The conveyance system is sized to accommodate 20 mgd, the groundwater recharge flow. For the lime treatment of brine reject option, a brine disposal pipeline of 6,000 feet would be required for conveying RO brine reject to a new outfall in the San Francisco Bay. The zero brine discharge option does not require additional conveyance pipelines.

- Alternative 2—Groundwater recharge treatment plant location would be near the Guadalupe recharge ponds. The conveyance system consists of a 80,000-foot trunk line (approximate length) and three lateral pipelines totaling approximately 76,000 feet. The conveyance system is shown on Figure 8-2. The trunk line connects the nonpotable reclamation plant located near the SJ/SC WPCP to the groundwater recharge plant. This pipeline is shared with the nonpotable distribution system and is sized to accommodate both the nonpotable and groundwater recharge treatment plant influent flows. The lateral pipelines connect the groundwater recharge plant with each of the three recharge system ponds and are sized to handle the recharge flow for each recharge system. For the lime treatment of brine reject option, a brine disposal pipeline of 86,000 feet would be required for conveying RO brine reject to a new outfall in the San Francisco Bay. The zero brine discharge option does not require additional conveyance pipelines.

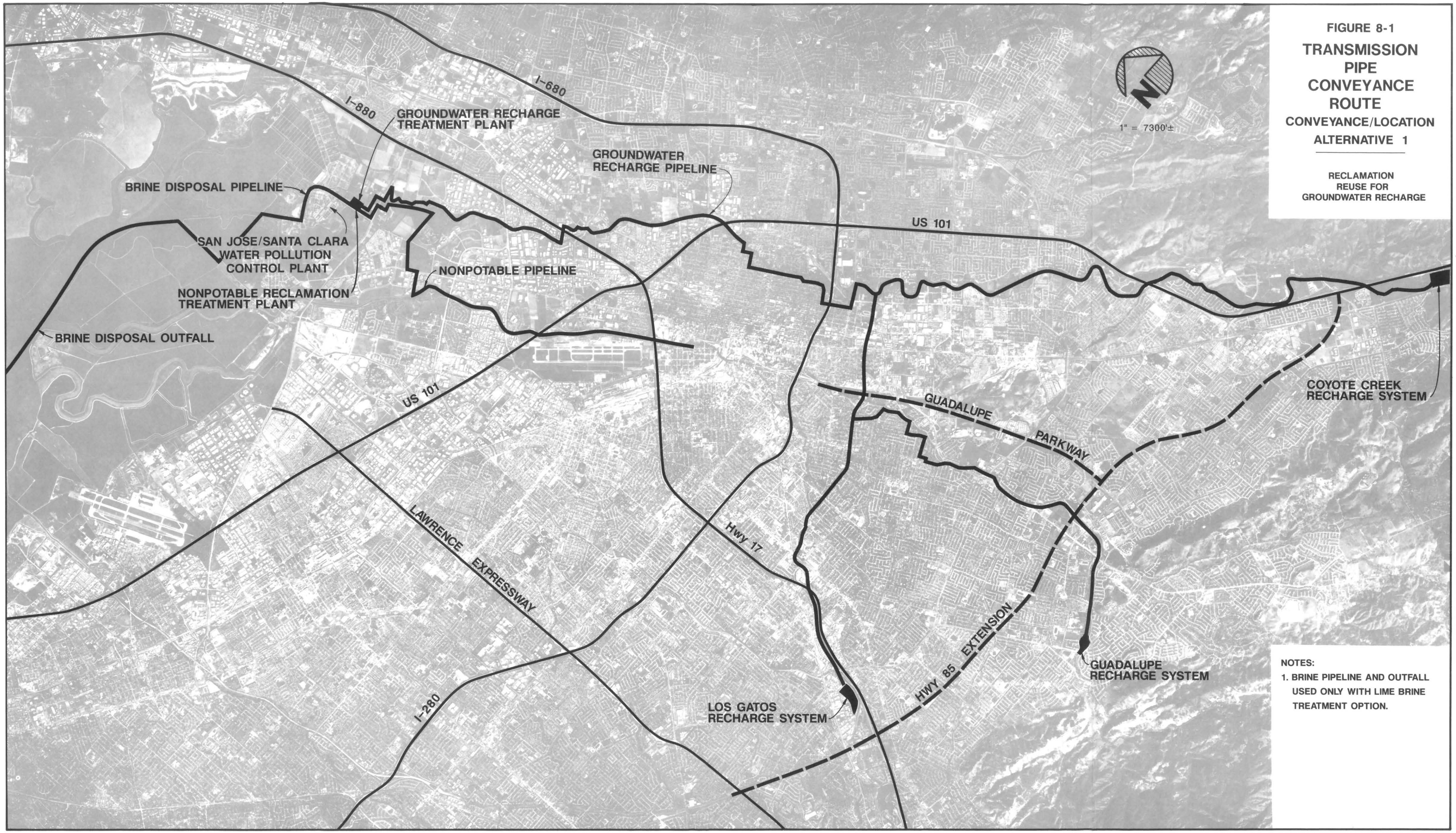

1" = 7300'±
N
I-680
I-880
GROUNDWATER RECHARGE TREATMENT PLANT
GROUNDWATER RECHARGE PIPELINE
BRINE DISPOSAL PIPELINE
SAN JOSE/SANTA CLARA WATER POLLUTION CONTROL PLANT
NONPOTABLE PIPELINE
NONPOTABLE RECLAMATION TREATMENT PLANT
BRINE DISPOSAL OUTFALL
US 101
US 101
COYOTE CREEK RECHARGE SYSTEM
GUADALUPE PARKWAY
LAWRENCE EXPRESSWAY
Hwy 17
HWY 85 EXTENSION
I-280
GUADALUPE RECHARGE SYSTEM
LOS GATOS RECHARGE SYSTEM

FIGURE 8-1

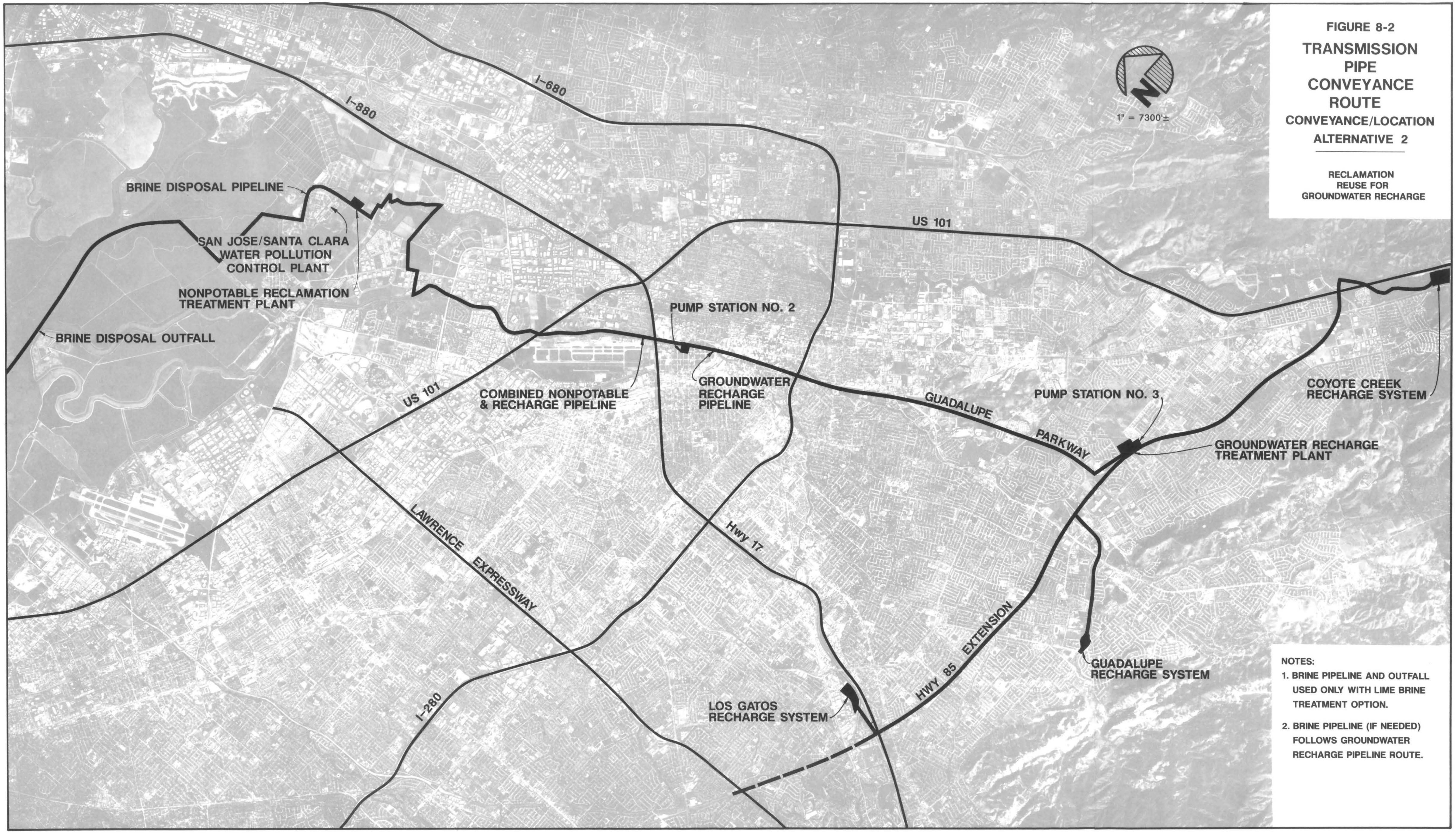
TRANSMISSION PIPE CONVEYANCE ROUTE

CONVEYANCE/LOCATION ALTERNATIVE 1

RECLAMATION
REUSE FOR
GROUNDWATER RECHARGE

NOTES:

1. BRINE PIPELINE AND OUTFALL USED ONLY WITH LIME BRINE TREATMENT OPTION.



1" = 7300'±
I-680
I-880
US 101
BRINE DISPOSAL PIPELINE
SAN JOSE/SANTA CLARA WATER POLLUTION CONTROL PLANT
NONPOTABLE RECLAMATION TREATMENT PLANT
BRINE DISPOSAL OUTFALL
PUMP STATION NO. 2
US 101
COMBINED NONPOTABLE & RECHARGE PIPELINE
GROUNDWATER RECHARGE PIPELINE
GUADALUPE PARKWAY
PUMP STATION NO. 3
COYOTE CREEK RECHARGE SYSTEM
GROUNDWATER RECHARGE TREATMENT PLANT
LAWRENCE EXPRESSWAY
Hwy 17
HWY 85 EXTENSION
I-280
LOS GATOS RECHARGE SYSTEM
GUADALUPE RECHARGE SYSTEM

FIGURE 8-2

TRANSMISSION PIPE CONVEYANCE ROUTE

CONVEYANCE/LOCATION ALTERNATIVE 2

RECLAMATION
REUSE FOR
GROUNDWATER RECHARGE

NOTES:

1. BRINE PIPELINE AND OUTFALL USED ONLY WITH LIME BRINE TREATMENT OPTION.
2. BRINE PIPELINE (IF NEEDED) FOLLOWS GROUNDWATER RECHARGE PIPELINE ROUTE.

- Alternative 3—Groundwater recharge treatment plant location would be near the SJ/SC WPCP with a series of injection wells located near the San Francisco Bay. The conveyance system would also provide import water for dilution purposes, since the maximum recharge concentration allowed in the draft DOHS groundwater recharge regulations is 50 percent reclaimed water. The groundwater local model work has therefore a cost estimate been developed for Alternative 3, nor have the costs been estimated.

- Alternative 4—Groundwater recharge treatment plant would be located near SJ/SC WPCP on the Zanker Road site. The conveyance system will link the plant to a series of injection wells located in the groundwater basin forebay area. The conveyance system must also deliver dilution water (raw import water) from the central pipeline to the groundwater recharge treatment plant, sized for 20 mgd. The conveyance system from the groundwater recharge treatment plant to the direct injection wells is sized for 40 mgd (20 mgd reclaimed water and 20 mgd dilution water). Figure 8-3 shows the conveyance system and the possible location of one 25-mgd well field. The actual location of the injection wells has not been determined and is shown for concept only. For the lime treatment of brine reject option, a brine disposal pipeline of 6,000 feet would be needed.

Many other treatment and conveyance combinations are possible, such as locating the groundwater recharge treatment plant near the SJ/SC WPCP and conveying recharge water to a combination of injection wells and some portion of one or more of the three recharge systems. These other combinations are not evaluated in this report.

Transmission Pipe Conveyance Routes

Installation of pipelines, particularly large diameter ones within city streets with their myriad of existing underground utilities is a major cost item. In addition, the disruption to traffic and construction-related occurrences are typically considered major inconveniences to the general public. For the groundwater recharge alternatives, the incremental cost of construction in a city street would be prohibitively expensive.

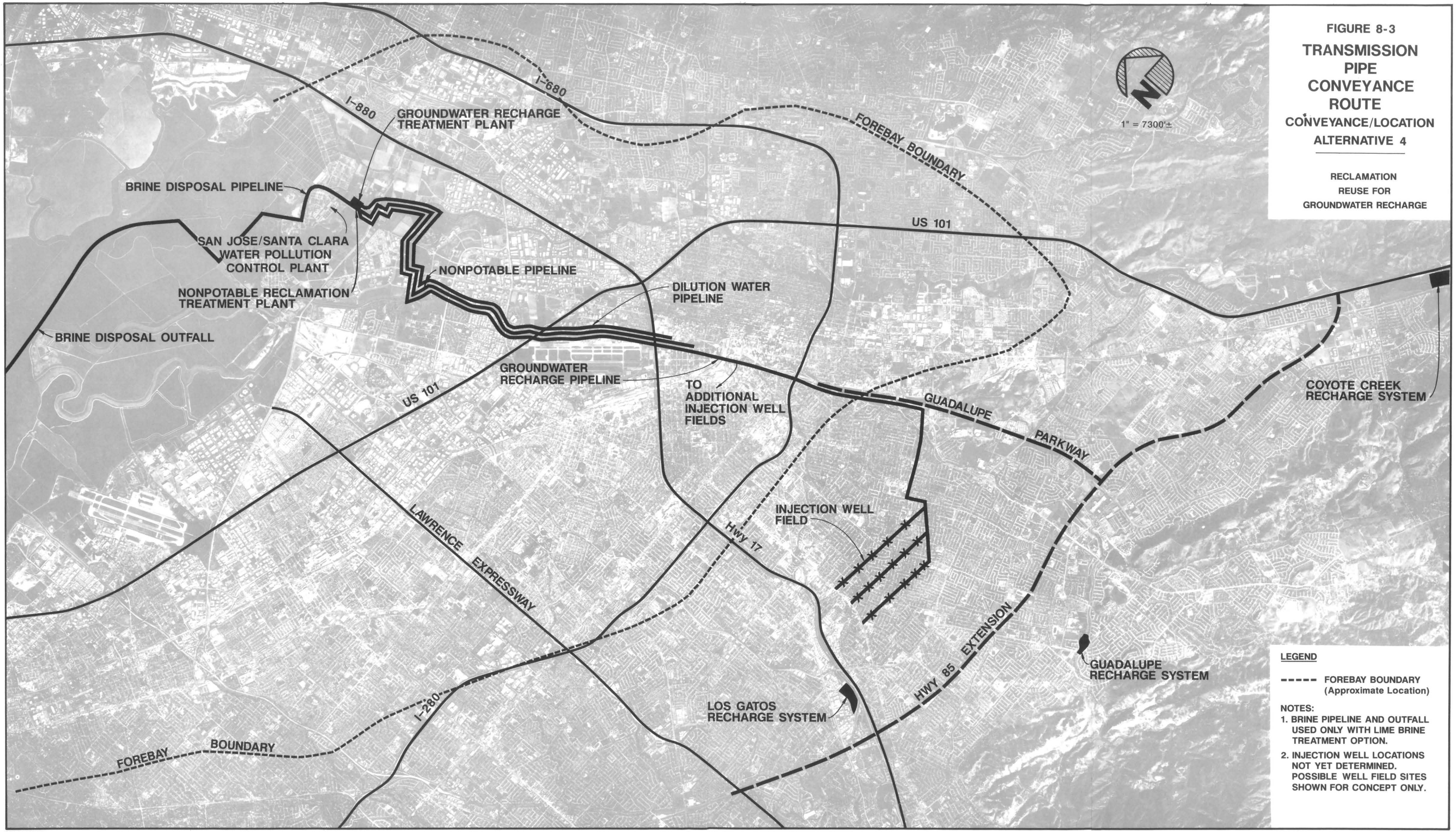
Routing of conveyance pipelines has therefore focused on open corridors, such as the flood control right-of-way along the major creeks. Fortunately, flood control right-of-way exists along the major creeks that are linked to the Los Gatos, Guadalupe, and Coyote recharge systems. Significant greenbelts are also planned along major portions of Coyote Creek, Guadalupe River, and Los Gatos Creek. Many segments of these major streams have been channelized and diked for flood control. The flood control facilities and rights-of-way are owned and maintained by the SCVWD. However, there are also segments where the streams have not been improved for flood control or where significant right-of-way is not available.

FIGURE 8-3

TRANSMISSION PIPE CONVEYANCE ROUTE

CONVEYANCE/LOCATION ALTERNATIVE 4

RECLAMATION
REUSE FOR
GROUNDWATER RECHARGE


1" = 7300'±
N
I-680
I-880
GROUNDWATER RECHARGE TREATMENT PLANT
FOREBAY BOUNDARY
BRINE DISPOSAL PIPELINE
SAN JOSE/SANTA CLARA WATER POLLUTION CONTROL PLANT
NONPOTABLE PIPELINE
US 101
NONPOTABLE RECLAMATION TREATMENT PLANT
DILUTION WATER PIPELINE
BRINE DISPOSAL OUTFALL
GROUNDWATER RECHARGE PIPELINE
TO ADDITIONAL INJECTION WELL FIELDS
US 101
GUADALUPE PARKWAY
COYOTE CREEK RECHARGE SYSTEM
INJECTION WELL FIELD
LAWRENCE EXPRESSWAY
Hwy 17
HWY 85 EXTENSION
GUADALUPE RECHARGE SYSTEM
LOS GATOS RECHARGE SYSTEM
I-280
FOREBAY BOUNDARY

LEGEND

---- FOREBAY BOUNDARY (Approximate Location)

NOTES:

1. BRINE PIPELINE AND OUTFALL USED ONLY WITH LIME BRINE TREATMENT OPTION.
2. INJECTION WELL LOCATIONS NOT YET DETERMINED. POSSIBLE WELL FIELD SITES SHOWN FOR CONCEPT ONLY.

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The first possibility for a conveyance route would be to use SCVWD flood control rights-of-way. This involves a parallel encroachment in the SCVWD flood control right-of-way. This concept was discussed with the flood control division staff. Although SCVWD policy is generally to discourage parallel encroachments in SCVWD rights-of-way, staff indicated that a parallel encroachment may be implementable. This investigation assumed that a permit could be obtained from SCVWD for installing a reclaimed water pipeline running parallel in SCVWD right-of-way. A significant issue regarding construction along the right-of-way is the potential adverse impact it may have on the riparian habitat that exists along the creeks. This is most important in creek channel areas that have not been modified for flood control purposes. Mitigation measures to establish riparian habitat may be required. A joint project with the flood control improvements by the SCVWD may be possible in these unimproved areas.

A second possibility for a conveyance route exists in the area between Highway 237 and I-880. In this area open land still exists outside the stream channel, which might be used for pipeline construction. During a field review of the pipeline routes, it was determined that locating a pipeline along the Guadalupe River and Los Gatos Creek, between I-880 and I-280, would be extremely difficult because of the lack of adequate right-of-way. This was verified by the SCVWD.

Therefore, for Alternative 1, an alignment was developed that routes all the groundwater recharge flow along Coyote Creek until the pipeline reaches Alma Avenue (see Figure 8-1). At this location a branch pipeline is routed to the west to intersect the alignment of the Guadalupe River and Los Gatos Creek pipelines; the main pipeline continues up Coyote Creek. This alignment effectively eliminates the need to install pipelines through downtown San Jose.

For Alternative 2, the trunk line carrying the nonpotable and groundwater recharge flow follows Coyote Creek right-of way to San Jose Municipal Airport, where it follows south along the boundary of the airport and then along Guadalupe parkway until it reaches the groundwater recharge plant. From the recharge plant, lateral pipelines extending along the Highway 85 extension would convey treated water to the recharge pond systems. The pipeline configuration is shown on Figure 8-2. In the past, a parallel encroachment would have been essentially prohibited along Guadalupe Parkway and the Highway 85 extension. Current state legislation, however, allows parallel encroachments for reclamation purposes, although Caltrans requirements must be met. Resolving Caltrans concerns and other obstacles would require significant coordination during the predesign and design phases of the project.

Conveyance routes for Alternative 4 are similar to Alternative 2 following Coyote Creek and Guadalupe Parkway to the forebay area. Actual distribution routes to the injection wells have not been developed.

Transmission Pipeline Sizing

For Alternative 1, the trunk line has been sized for 20 mgd. This matches the production capacity of the groundwater recharge treatment plant. The branch lines to the Los Gatos, Guadalupe, and Coyote Creek recharge systems have been sized for 8.5, 5.4, and 6.1 mgd, respectively: splitting the 20 mgd in proportion to the current recharge operation flows.

For Alternative 2, the trunk line has been sized for 93.5 mgd, which includes 68.5 mgd of nonpotable flow at the beginning of the trunk line and 25 mgd for the last section of trunk line. The first 42,000 feet of pipe has been sized to accommodate both nonpotable and the recharge flows. The lateral lines to the three recharge systems from the groundwater recharge treatment plant have been sized for the same 8.5, 5.4, and 6.1 mgd flow rates as discussed in Alternative 1.

Transmission pipeline sizes were selected based on an economic analysis of various pump sizes and piping combinations. The analysis determined the lowest combination of capital costs and annual O&M costs for several alternatives.

Transmission pipe sizes for Alternatives 1 and 2 are listed in Table 8-1. Table 8-2 is a summary of pipeline unit costs. The Alternative 2 routing is shorter than the Alternative 1 routing. Transmission pipe sizes were calculated for a nonpotable only system in Alternative 2 so that the nonpotable portion of pipeline costs could be subtracted from the combined nonpotable and recharge pipeline costs.

Table 8-1
Summary of Pipeline Diameters and Estimated Lengths

Pipe Diameter	Alternative 1 (LF)	Alternative 2 Combined Nonpotable Recharge (LF)	Alternative 2 Nonpotable Only (LF)	Alternative 4[a] (LF)
54	--	22,000	--	--
48	--	--	--	61,000
42	--	20,000	4,000	--
39	58,000	38,000	5,000	10,000
36	--	--	13,000	40,000[b]
33	--	--	--	4,000
30	10,000	7,000	--	--
24	24,000	29,000	20,000	17,000
21	56,000	30,000	--	--
18	36,000	10,000	--	20,000
16	--	--	--	13,000

[a] Lengths estimated to 25-mgd well field only, as shown on Figure 8-3.
[b] Dilution water supply pipeline.

Table 8-2
Pipeline Unit Costs

Pipe Diameter	Relative Unobstructed Construction Unit Cost ($/LF)	Relatively Obstructed Construction Unit Cost ($/LF)
72	431	560
66	392	514
60	349	461
54	301	400
48	263	354
42	211	286
39	193	266
36	175	247
33	159	225
30	143	202
24	98	170
21	84	145
18	67	143
16	50	127

Note:
Costs are in 1992 dollars and are based on mortar cement-lined steel pipe with an allowance for pavement repair, utility interferences, and cathodic protection. Relatively unobstructed construction refers to pipeline installation along flood control areas and creekbanks. Relatively obstructed construction refers to pipeline installation along city streets.

Transmission Pipe Ancillary Facilities

For Alternative 1, one main pump station would be required to provide a 20-mgd pumping capacity. The pump station size is estimated to be 1,800 horsepower (hp). The delivery pressure of the groundwater recharge water is assumed to be 20 pounds per square inch gauge (psig).

For Alternative 2, three pump stations would be required. The first pump station would be located adjacent to the nonpotable reclamation plant and would accommodate both nonpotable and recharge flows. This station would be rated for approximately 4,250 hp. The second pump station would be located at the end of the combined nonpotable and recharge pipeline near the San Jose Municipal Airport. This pump station would transmit recharge flows to the groundwater recharge treatment plant. This station would be rated for approximately 1,350 hp. The third pump station would be located at the end of the groundwater recharge treatment plant and would pump to the three recharge system ponds. This pump station is estimated to be approximately 200 hp. The combined horsepower of the three pump stations is approximately 5,800 hp.

A pump station for a nonpotable only system would require approximately 5,000 hp compared to approximately 4,250 hp for a combined system. Although there is less flow associated with a nonpotable only system, there are greater head losses because of the smaller pipe diameters in the nonpotable only system. The most economical pipe size was determined for both the combined system and the nonpotable only system. However, the nonpotable only system's pipelines are sized closer to their capacity, which explains the greater headlosses associated with the nonpotable only system. Therefore, the nonpotable only system is able to take advantage of greater economy on the pipeline cost by sacrificing economy on pump costs. Subtracting the nonpotable portion of horsepower will yield a net of approximately 800 hp attributable to recharge flows.

For Alternative 4, one main pump station would be required to provide a 40-mgd pumping capacity. The pump station size is estimated to be approximately 3,200 hp. The delivery pressure of the groundwater recharge water is estimated at 20 psig at the top of each injection well.

To deliver reclaimed water to the recharge facility, the main transmission pipeline must cross major streets, freeways, railroad tracks, and streams. The locations of some of these major facility crossings were estimated during a partial field review of pipeline routes. A lump sum cost for crossings is included in the construction cost estimates. Further analysis is required to refine these cost estimates.

It is likely that some recharge system improvements will be necessary at each recharge site (Los Gatos Creek, Guadalupe River, and Coyote Creek). These improvements will probably include additional onsite piping to distribute the reclaimed water and inlet structures to the basins, improvements not developed as part of this conceptual design investigation. Instead, to address these improvement needs, a lump sum was provided in the construction cost estimates.

Groundwater Recharge Facilities

Groundwater recharge facilities are the final conveyance step. Recharge is accomplished by either surface recharge using ponds and creeks or by direct injection recharge using direct injection wells.

Project Alternatives 1 and 2 both make use of the existing SCVWD surface recharge facilities. Conveyance cost estimates for Alternatives 1 and 2 do not include any capital or O&M costs for these existing surface water facilities.

Project Alternatives 3 and 4 assume recharge using new direct injection well facilities. Conveyance cost estimates for Alternative 4 do include both capital and O&M costs for the new injection well recharge facilities. Direct injection well cost estimates are shown in Table 8-3.

Table 8-3
Direct Injection Well Costs[a]

Item	Capital Cost ($1,000)	O&M Cost ($1,000/yr)
Well Installation[b]	450	--
Well Operations[c]	--	17
Total Per Well	450	17
Total for 19 Wells	8,600	320

[a] Based on 24-inch-diameter, 500-foot-deep injection wells with 200 feet of stainless steel screen.
[b] Includes recharge flow control and measurement, backflushing pump and piping, test well, initial injection testing, and disposal of cuttings.
[c] Includes regular well backflushing, redevelopment, and periodic testing.

Brine Disposal Conveyance

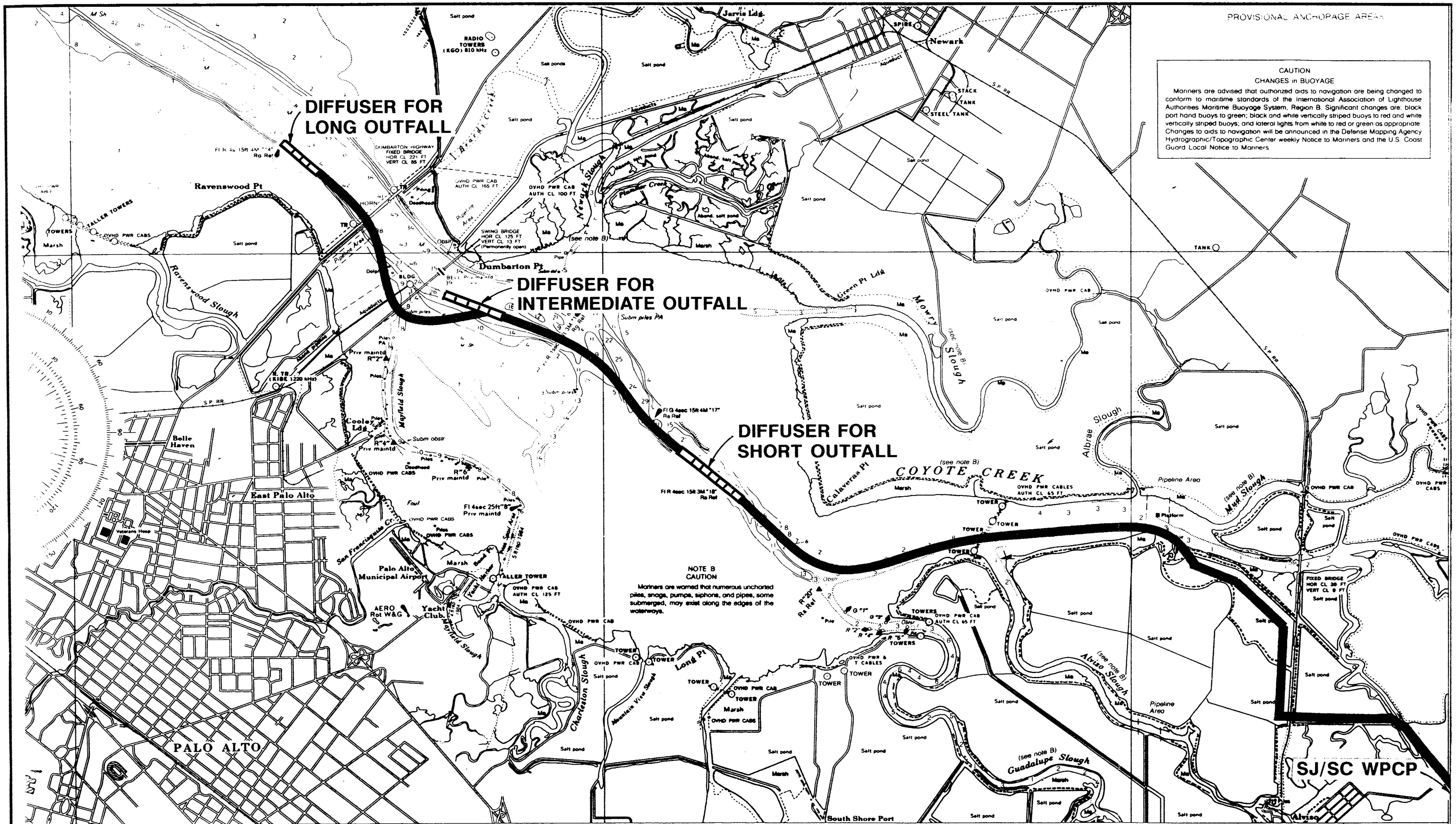
There are two options for disposal of brine reject from the RO process. One option is for lime treatment, filtration, RO, vapor compression evaporation, and forced circulation crystallization. This is essentially a zero brine discharge alternative and it does not affect conveyance costs. The other option is for lime treatment and lime sludge dewatering, with disposal of approximately 5 mgd of residual liquid to the San Francisco Bay using a new pipeline and outfall. The cost of a brine disposal pipeline and outfall is added to each alternative for the lime brine option only.

Brine Pipeline

A brine disposal pipeline is required from the Zanker Road groundwater recharge treatment plant to the new San Francisco Bay outfall if the lime brine treatment option is used. For Alternative 1, the brine disposal pipeline is approximately 6,000 feet long and follows Zanker Road to the outfall slough. For Alternative 2, the brine disposal pipeline is approximately 86,000 feet long and follows the groundwater recharge transmission pipeline from the groundwater recharge treatment plant back to the Zanker Road pumping site. From the Zanker Road site to the San Francisco Bay, the pipeline route is the same as described in Alternative 1.

Brine Outfall

A new outfall would be needed to dispose of lime-treated brine. In 1989 CH2M HILL and Larry Walker Associates prepared an Outfall Alternative Study for the City of San Jose. This study looked at three diffuser locations with an outfall aligned along what was referred to as the marine route, shown on Figure 8-4. The three diffuser locations are the long



CAUTION
CHANGES in BUOYAGE
Mariners are advised that authorized aids to navigation are being changed to conform to maritime standards of the International Association of Lighthouse Authorities Maritime Buoyage System, Region B. Significant changes are: black port hand buoys to green; black and white vertically striped buoys to red and white vertically striped buoys; and lateral lights from white to red or green as appropriate. Changes to aids to navigation will be announced in the Defense Mapping Agency Hydrographic/Topographic Center weekly Notice to Mariners and the U.S. Coast Guard Local Notice to Mariners.

NOTE B
CAUTION
Mariners are warned that numerous uncharted piles, snags, pumps, siphons, and pipes, some submerged, may exist along the edges of the waterways.

SCALE: 1"=4000'

FIGURE 8-4
BRINE DISPOSAL
OUTFALL ALTERNATIVES

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outfall north of the Dumbarton Bridge, the intermediate outfall south of the Dumbarton Bridge, and the short outfall just north of Coyote Creek.

The Marine route was selected as the best for construction with the least environmental disturbance, based on an analysis of soil conditions and constructibility in water versus alternate congested land routes. The 1989 outfall study looked at outfall capacities ranging from 50 to 400 mgd, significantly larger than the 5 mgd being evaluated for lime brine disposal.

Permitting a new outfall would not be a simple task, so the feasibility of this lime brine option is not clear. For the sake of cost estimating this option, Table 8-4 presents cost estimates for the short, intermediate, and long outfalls. These cost estimates include a pipeline across the salt pan from Zanker Road to the beginning of the bay outfall. These costs assume a 5-mgd capacity and similar piping materials and construction concepts as those developed in the 1989 Outfall Alternative Study. In fact, given that the pipe size for the brine outfall is significantly smaller than those in the 1989 effort, other pipe materials and methods of construction may be significantly less expensive. If a brine outfall is considered a viable option, then additional outfall evaluations and cost estimates would be recommended.

Table 8-4
Brine Disposal Outfall Costs

Diffuser Location	**Capital Cost ($1,000)**	**O&M Cost ($1,000/yr)**
Short	58,600	540
Intermediate	68,300	710
Long	77,000	850

Notes:

Outfall capacity: 5 mgd
Outfall diameter: 24 inch
1992 dollars
All routing and design assumptions taken from the 1989 report for City of San Jose "Cease and Desist Order, Outfall Alternative Study, Permit Assistance Program."

Estimated Conveyance System Costs

Basis of Cost Estimates

The accuracy of the costs estimated for the conveyance system is based on order of magnitude. This type of estimate is expected to be accurate within +50 to -30 percent. Order-of-magnitude estimates are prepared without detailed engineering analysis of the various system components or site data. The estimates are based on conceptual plans of the conveyance system and general cost-curve information for the various components.

The cost estimates have been prepared for guidance in project evaluation and implementation from information available at the time the estimate was prepared. The final costs of the project and resulting feasibility will depend on several variable factors. As a result, the final project costs will vary from the estimates presented. All costs are presented in 1992 dollars and can be escalated to 1999, the estimated midpoint of construction, by multiplying by a factor of 1.44 (assuming 5 percent yearly inflation).

Estimated Capital Costs

The purpose of the construction cost estimate is to provide a general indication of the approximate implementation costs associated with the representative reuse options described previously. These costs were prepared for the conveyance system components based on the conceptual design information developed in this investigation and include the contractor's overhead, profit, and mobilization. Additional costs for engineering and contract administration were also included based on 20 percent of the estimated construction costs. Thus, the total capital cost of the conveyance system is the sum of the estimated construction, engineering, and administration costs.

Table 8-5 summarizes the estimated capital costs for alternative conveyance system components. The costs associated with supplying the nonpotable portion of conveyance system capacity have been subtracted from Alternative 2. Costs have not been estimated for Alternatives 3 or 4 because the number and location of injection wells will not be available until after the groundwater model study is complete.

Estimated Operations and Maintenance Costs

Estimates were prepared for the annual operations and maintenance costs associated with the conveyance system alternatives. These estimates were based on typical maintenance costs as a percentage of initial construction costs for the pump station and pipeline and estimated power consumption for the pump station. The power costs were based on a unit power cost of $0.071 per kW-hr (based on PG&E Schedule E20). The maintenance costs include labor to perform the maintenance on the facilities. No other labor costs have been included in the estimate.

Table 8-5
Summary of Estimated Construction Costs[a]
($1,000)

Conveyance Pipeline Component	Alternative 1 Cost ($1,000)	Alternative 2 Cost ($1,000)	Alternative 4 Cost[d] ($1,000)
Conveyance Pipeline	22,100	19,600	36,000
Direct Injection Wells (19 total)	--	--	8,600
Dilution Water Pipeline	[b]	[b]	9,600
Highway, Railroad, and Creek Crossings	3,800	3,800	3,800
Pump Station	1,800	300	3,200
Recharge Basin Improvements	600	600	600
Wetlands Mitigation	3,000	3,000	3,000
Brine Disposal Pipeline[c]	500	9,600	500
Contingency/Engineering with Zero Brine Discharge	14,100	12,500	29,200
TOTAL with Zero Brine Discharge	45,400	40,400	85,600
Contingency/Engineering with Lime Treatment of Brine Reject	14,300	16,800	29,500
TOTAL with Lime Treatment of Brine Reject	46,100	54,600	95,000

[a] All estimated costs are in 1992 dollars. Capital costs include a 20% allowance for engineering, legal, and administrative costs. Conveyance alternatives are shown on Figures 8-1, 8-2, and 8-3.

[b] Dilution water pipeline costs not included. Local water at the existing recharge facilities will be used.

[c] Includes pipeline from groundwater recharge treatment plant to the Zanker Road slough. Pipeline costs across the salt pan included with outfall costs.

[d] Alternative 4 pipeline costs based on estimated lengths, as shown in Table 8-1, to the 25-mgd well field. These costs then extrapolated to possible well field site west and south of Los Gatos Creek, including a 25% safety factor.

Estimated Equivalent Annualized Cost

The estimated equivalent annualized cost was developed by analyzing the construction costs and adding the annual O&M costs. The construction costs were annualized over a 20-year period at an annual interest rate of 8-7/8 percent.

The estimated annualized cost of the conveyance system, including capital and O&M, is $396/ac-ft/yr (22,400 ac-ft/yr) for Alternative A with zero brine discharge. The annualized cost of the conveyance system is $406/ac-ft/yr (22,400 ac-ft/yr) for Alternative 1 with lime treatment and disposal of brine reject with zero brine discharge to the San Francisco Bay. The estimated annualized cost for Alternative 2 is $372/ac-ft/yr (22,400 ac-ft/yr). The annualized cost of the conveyance system with zero brine discharge is $445/ac-ft/yr

(22,400 ac-ft/yr) for Alternative 2 with lime treatment and disposal of brine reject to the San Francisco Bay.

Blue Ribbon Committee Comments

Mr. Lauer commented that in the Denver Reuse project the low TDS RO effluent will be blended with other process unit waters to control water aggressiveness in the conveyance pipelines, while retaining the taste benefit of lowering the overall TDS. He suggested that blending or alternative conveyance materials be considered as an alternative to adding back hardness into the RO product water.

Chapter 9
Cost Estimates

Chapter 9
Cost Estimates

Basis of Estimates

The cost estimates presented in Table 9-1 are based on the costs that were developed in the previous chapters for treatment and conveyance pipelines. The cost estimates do not include the price of land or the cost of financing.

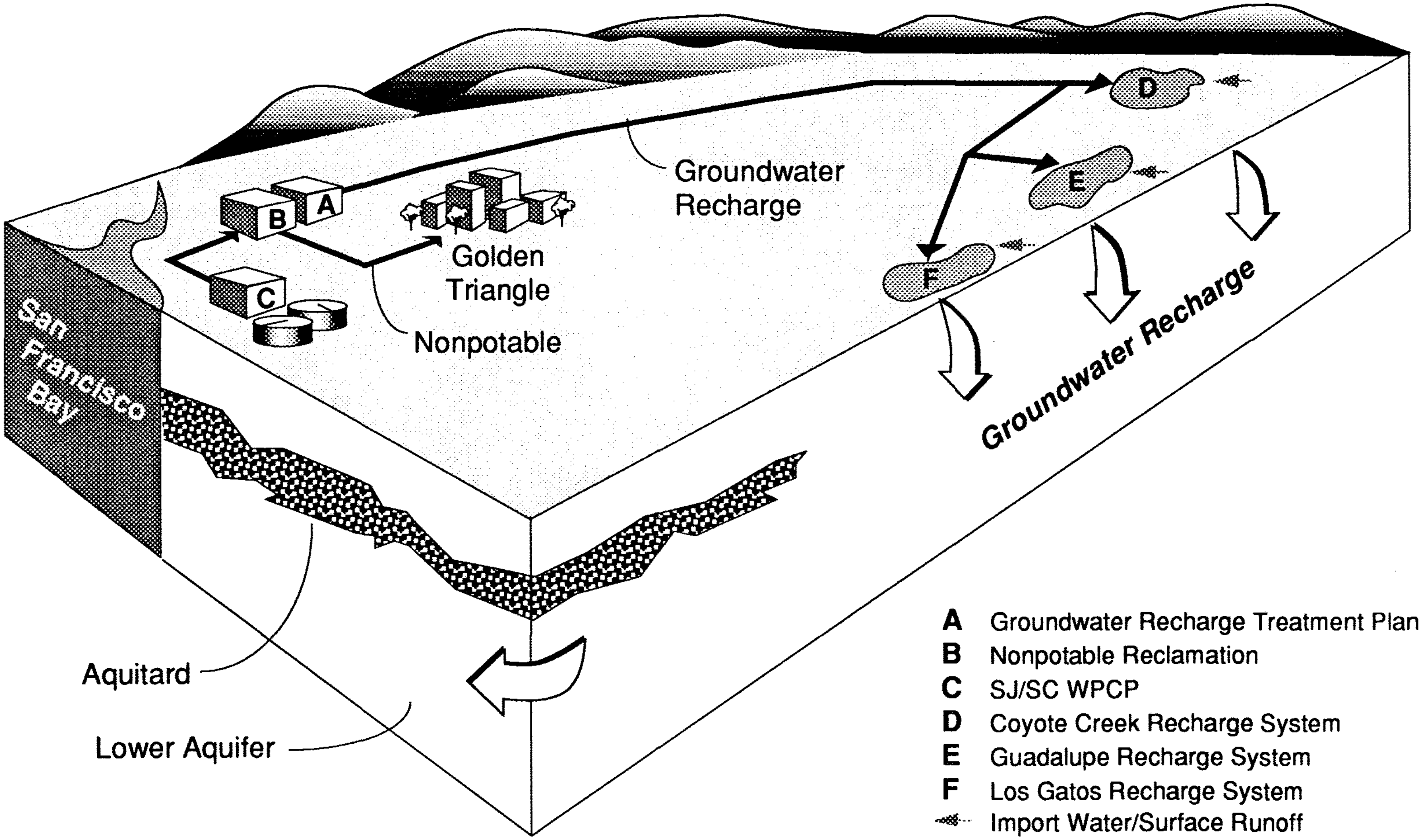
The accuracy of the costs estimated is order of magnitude. This type of estimate is expected to be accurate within +50 to -30 percent. Order-of-magnitude estimates are prepared without detailed engineering analysis of the various system components or site data. The estimates are based on conceptual plans of the conveyance system and general cost-curve information for the various components.

The costs estimates have been prepared for guidance in alternative project evaluation from the information available at the time the estimate was prepared and are not intended to reflect the actual cost of water production. The final costs of the project and resulting feasibility will depend on a number of variable factors including changes in state and/or federal treatment standards. As a result, the final project costs will vary from the estimates presented in this report.

Specific assumptions include:

- All costs are in 1992 dollars for the San Francisco Bay Area. Cost estimates can be escalated to the approximate midpoint of construction, assumed to be 1999, by multiplying by a factor of 1.44, assuming 5 percent annual inflation.
- Capital costs include a 20 percent allowance for engineering, administrative, and legal costs.
- Power costs are estimated to be $0.071 per kW-hr.
- Costs are annualized using a discount rate of 8-7/8 percent for 20 years.
- Cost of piles not included, will be estimated during next phase of work.

Four combined treatment and conveyance/location alternatives have been identified, and are graphically summarized on Figures 9-1, 9-2, 9-3, and 9-4. The cost estimates for the treatment and conveyance/location alternatives are summarized in Table 9-1. Table 9-2 summarizes the average cost per project alternative, divided to show the difference in cost between the treatment alternatives meeting the composite standards versus those meeting the groundwater nondegradation standards. Table 9-2 averages



A Groundwater Recharge Treatment Plant
B Nonpotable Reclamation
C SJ/SC WPCP
D Coyote Creek Recharge System
E Guadalupe Recharge System
F Los Gatos Recharge System
⇠ Import Water/Surface Runoff

Brine Line Pipeline/Outfall not Shown

FIGURE 9-1
CONVEYANCE/LOCATION
Alternative 1

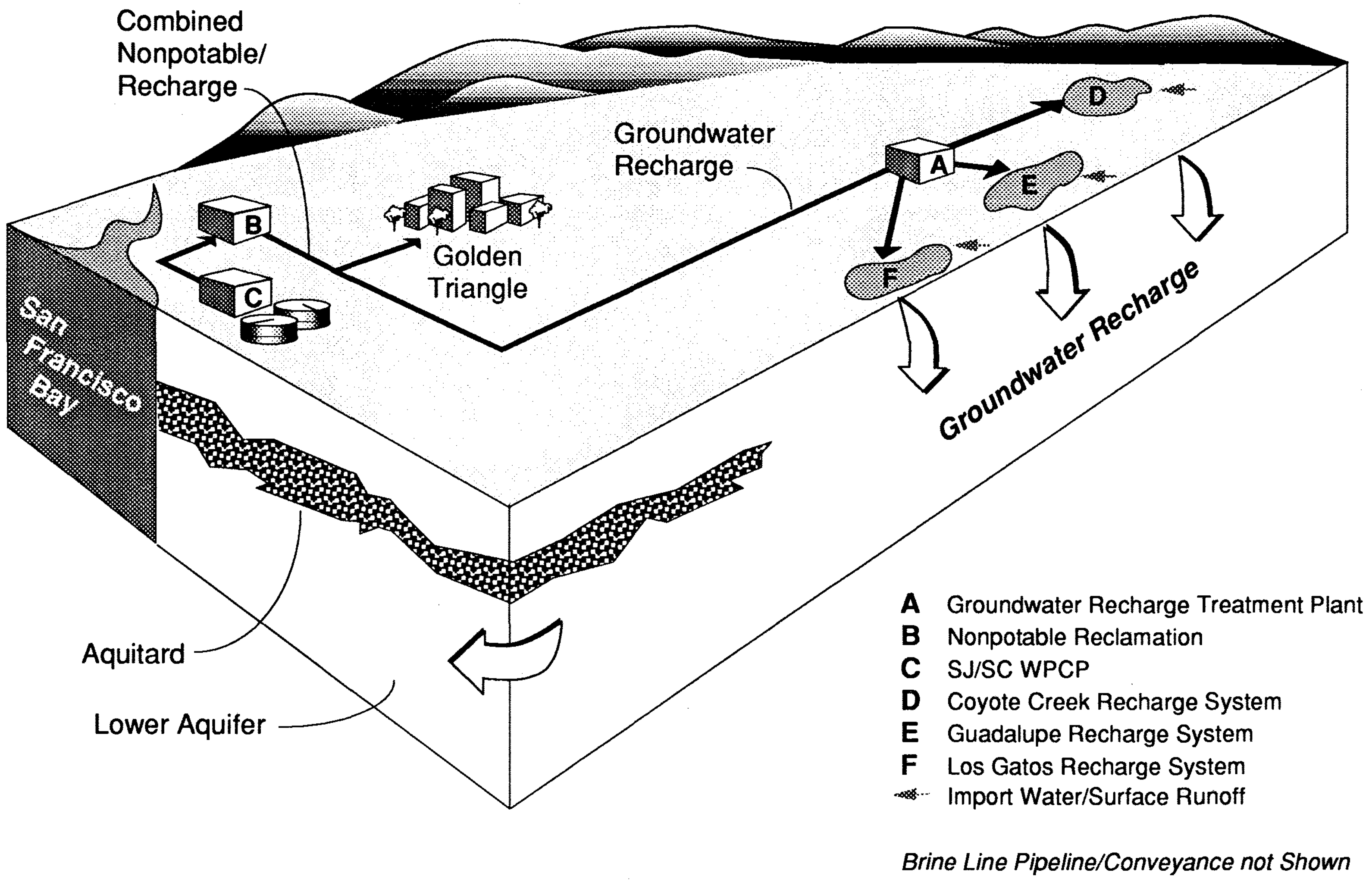
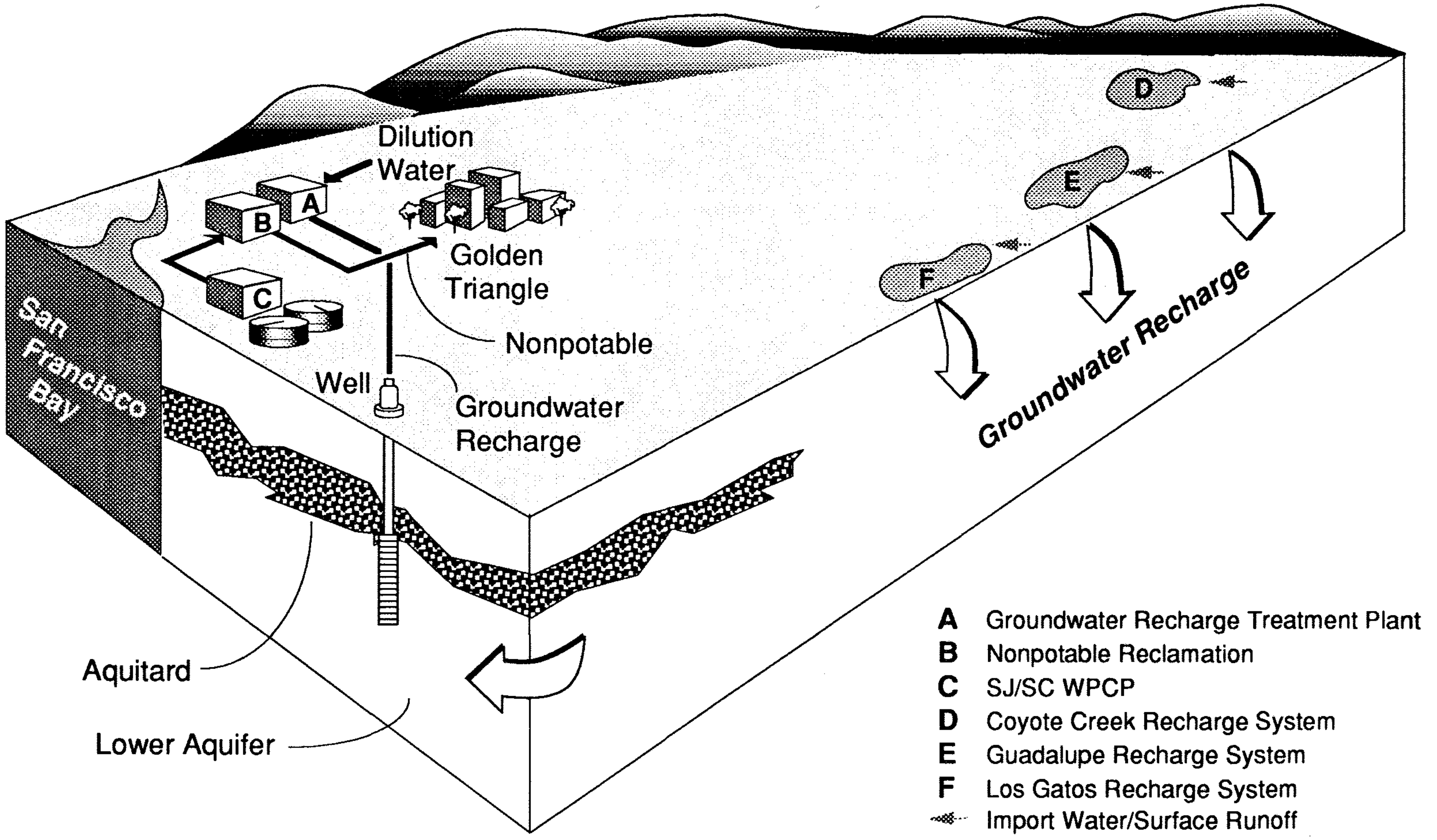
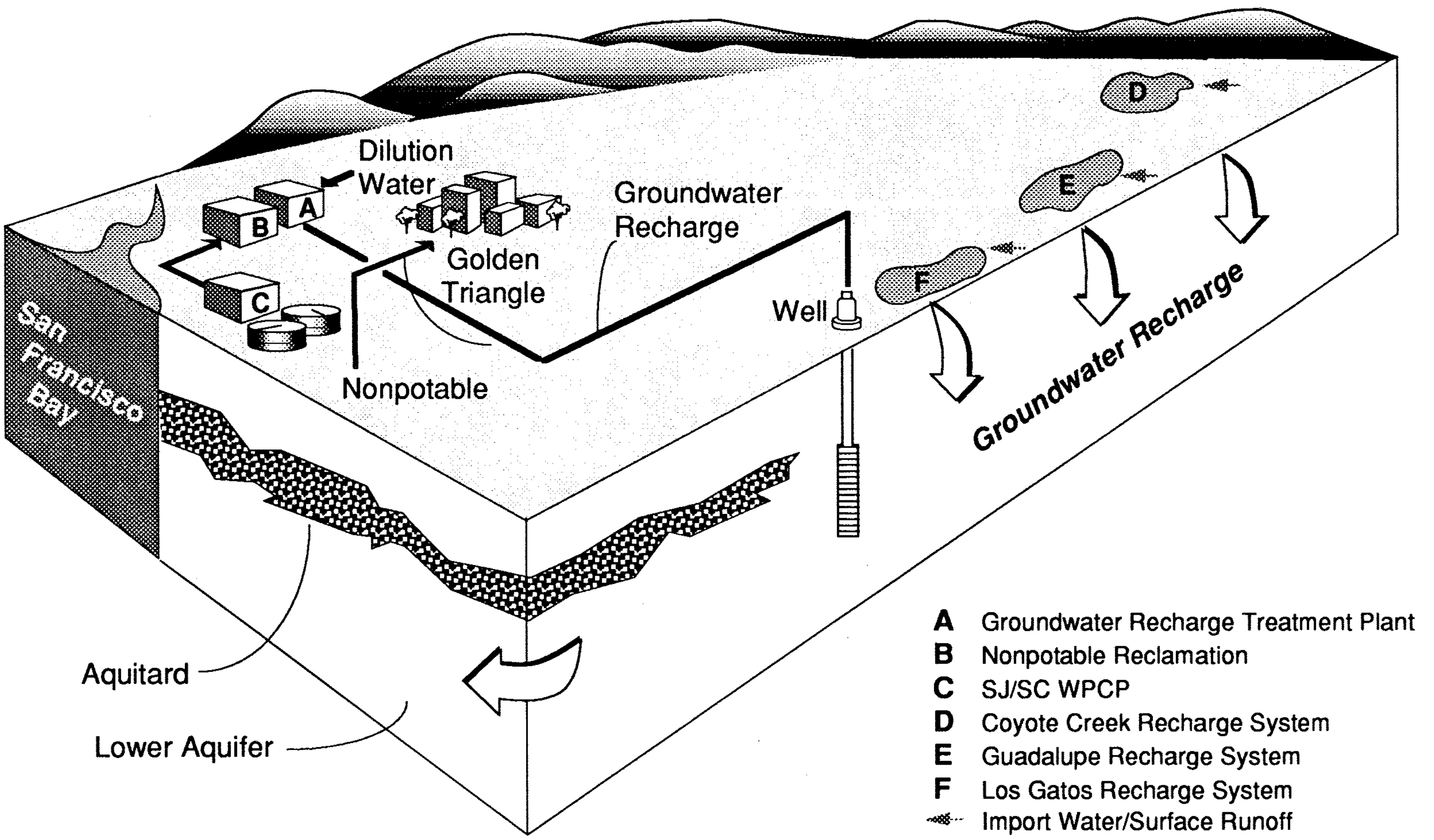

Combined Nonpotable/ Recharge
Groundwater Recharge
A
D
E
B
Golden Triangle
F
C
San Francisco Bay
Groundwater Recharge
Aquitard
Lower Aquifer
A Groundwater Recharge Treatment Plant
B Nonpotable Reclamation
C SJ/SC WPCP
D Coyote Creek Recharge System
E Guadalupe Recharge System
F Los Gatos Recharge System
Import Water/Surface Runoff
Brine Line Pipeline/Conveyance not Shown

FIGURE 9-2
CONVEYANCE/LOCATION
Alternative 2



Brine Line Pipeline/Outfall not Shown.
Dilution Water Piping from Central Pipeline not Shown.

FIGURE 9-3
CONVEYANCE/LOCATION
Alternative 3



Brine Line Pipeline/Outfall not Shown.
Dilution Water Piping from Central Pipeline not Shown.

FIGURE 9-4
CONVEYANCE/LOCATION
Alternative 4

Table 9-1
Average Estimated Project Costs[a]

Project Alt. No.[h]	Plant Location/Brine Disposal Alternative[b]	Capital[d] ($1,000,000)			O&M Costs ($1,000,000/yr)			Annual Cost ($1,000,000)	Water Cost[f] ($ per acre-foot)
		Treatment[c]	Conveyance[g]	Total	Treatment[e]	Conveyance[g]	Total	Total	Total
Composite Standards									
1	WPCP/LB	$157	$47	$204	$19	$1	$20	$43	$1,903
2	Forebay/LB	$157	$55	$212	$19	$1	$20	$43	$1,920
4	WPCP/LB	$174	$96	$271	$23	$2	$25	$55	$2,440
1	WPCP/ZD	$94	$46	$140	$24	$1	$25	$40	$1,806
2	Forebay/ZD	$94	$41	$135	$24	$1	$25	$39	$1,759
4	WPCP/ZD	$111	$87	$197	$28	$2	$30	$52	$2,302
Nondegradation Standards									
1	WPCP/LB	$176	$47	$223	$22	$1	$23	$48	$2,124
2	Forebay/LB	$176	$55	$231	$22	$1	$23	$48	$2,141
4	WPCP/LB	$193	$96	$289	$26	$2	$28	$60	$2,662
1	WPCP/ZD	$112	$46	$158	$27	$1	$29	$46	$2,044
2	Forebay/ZD	$112	$41	$153	$27	$1	$28	$45	$1,997
4	WPCP/ZD	$129	$87	$216	$31	$2	$33	$57	$2,540

[a] All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life. Average costs are presented for treatment alternatives meeting the composite standard (Treatment Alternatives 1,2,3,4,5) and for treatment alternatives meeting the nondegradation standard (Treatment Alternatives 1A, 4A).

[b] Groundwater recharge treatment plant locations: WPCP = near SJ/SC WPCP, Forebay
Brine Disposal Options: LB = lime brine treatment with outfall, ZD = zero brine discharge

[c] Treatment capital costs include outfall capital costs of $65.0 million for alternatives with the lime brine disposal option.

[d] Capital costs include a 20% allowance for engineering, legal, and administrative costs.

[e] Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.

[f] Water costs are based on production of 20 mgd (22,400 ac-ft/yr) and include outfall costs of $353/AF for alternatives with the lime brine disposal option.

[g] Conveyance costs identical for all alternatives using lime brine treatment and outfall disposal.

[h] Alternative numbers correspond to those shown in Figure 3.

Table Updated February 1993

Table 9-2
SUMMARY OF ESTIMATED PROJECT COSTS(a)

Treatment Alternative(b)	Water Costs(d) ($/ac-ft)			
	Project Alternative 1	Project Alternative 2	Project Alternative 3	Project Alternative 4
LB-1	$1,990	$2,008	-	$2,528
LB-2	$1,853	$1,870	-	$2,390
LB-3	$1,871	$1,888	-	$2,408
LB-4	$1,964	$1,981	-	$2,501
LB-5	$1,836	$1,853	-	$2,374
ZD-1	$1,913	$1,866	-	$2,409
ZD-2	$1,623	$1,576	-	$2,119
ZD-3	$1,816	$1,769	-	$2,312
ZD-4	$1,890	$1,843	-	$2,386
ZD-5	$1,788	$1,741	-	$2,284
LB-1A	$2,055	$2,073	-	$2,593
LB-4A	$2,193	$2,210	-	$2,730
ZD-1A	$1,964	$1,916	-	$2,459
ZD-4A	$2,125	$2,077	-	$2,620

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.

(b) Alternatives are shown schematically in Figures 9-1 through 9-4.
LB Lime Brine Reverse Osmosis Brine Treatment
ZD Zero Discharge Brine Treatment
1A and 4A meet groundwater nondegradation standards
1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

the cost of different treatment alternatives. Tables 9-3 through 9-8 provide detailed capital and O&M cost breakdowns for each project Alternative 1, 2, or 4, for each of the combinations of treatment standards (either composite or groundwater nondegradation) and brine treatment (either lime treatment or zero brine discharge). Detailed development of the treatment alternatives, treatment standards, brine treatment, and conveyance alternatives can be found in Chapters 6, 7, and 8, including cost breakdowns. Chapter 8 discusses direct injection wells and associated costs. No costs were added to account for moving water supply wells.

The composite treatment standards have been developed by taking the most stringent standards for TDS, nitrate, and TOC. The nondegradation standards are from the state policy that says any groundwater recharge will not result in water quality less than the existing quality of the groundwater.

For each set of treatment standards there are two options for disposal of brine concentrate from the RO process. Brine lime treatment involves lime treatment of the brine and dewatering lime sludge. The brine lime treatment effluent is discharged to San Francisco Bay and the lime sludge is transported to a landfill. Zero brine discharge treatment involves lime treatment of the brine, filtration, and seawater-type membrane RO, with the seawater RO effluent returned for groundwater recharge. The brine reject from the seawater RO is then concentrated by vapor compression, crystallized, and encapsulated before disposal at a landfill.

There are four project alternatives, each with different groundwater recharge treatment plant locations and conveyance requirements. Alternative 1 is to locate a groundwater recharge treatment plant near the existing SJ/SC WPCP, on Zanker Road adjacent to the proposed nonpotable reclamation plant. The treated effluent would be conveyed through a trunk line and would branch to the recharge systems. Alternative 2 is to locate a treatment plant near the recharge systems. The conveyance system would consist of a transmission main from the nonpotable reclamation plant to the groundwater recharge treatment plant and three lateral pipelines from the groundwater recharge treatment plant to each of the recharge systems. Alternative 3 is to locate a groundwater recharge treatment plant on Zanker Road adjacent to the proposed nonpotable reclamation plant and convey the treated effluent to a nearby series of injection wells near San Francisco Bay. Injection near the San Francisco Bay appears impractical. Therefore, costs for Alternative 3 have not been estimated. Alternative 4 is to locate the groundwater recharge treatment plant on Zanker Road adjacent to the proposed nonpotable reclamation plant. Dilution water will also be conveyed to this site and treated. The blended reclaimed water and dilution water will then be conveyed to direct injection wells in the forebay area.

Detailed breakdowns of treatment and conveyance costs for each treatment alternative and locations are presented in Tables 9-3 through 9-8.

Table 9-3
BREAKDOWN OF ESTIMATED COSTS
PROJECT ALTERNATIVE 1, BRINE LIME TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/ac-ft)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
LB-1	$168	$46.7	$215	$19.9	$1.36	$21.3	$44.6	$1,990
LB-1A	$174	$46.7	$220	$20.8	$1.36	$22.1	$46.0	$2,055
LB-2	$163	$46.7	$210	$17.4	$1.36	$18.7	$41.5	$1,853
LB-3	$156	$46.7	$202	$18.6	$1.36	$19.9	$41.9	$1,871
LB-4	$157	$46.7	$203	$20.6	$1.36	$21.9	$44.0	$1,964
LB-4A	$179	$46.7	$226	$23.3	$1.36	$24.6	$49.1	$2,193
LB-5	$143	$46.7	$190	$19.1	$1.36	$20.5	$41.1	$1,836

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life. Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $65.0 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

Table 9-4
BREAKDOWN OF ESTIMATED COSTS
PROJECT ALTERNATIVE 1, ZERO BRINE DISCHARGE TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/ac-ft)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
ZD-1	$103	$45.9	$149	$25.3	$1.36	$26.7	$42.9	$1,913
ZD-1A	$108	$45.9	$153	$26.0	$1.36	$27.3	$44.0	$1,964
ZD-2	$94	$45.9	$140	$19.8	$1.36	$21.1	$36.4	$1,623
ZD-3	$93	$45.9	$139	$24.2	$1.36	$25.6	$40.7	$1,816
ZD-4	$94	$45.9	$140	$25.8	$1.36	$27.1	$42.4	$1,890
ZD-4A	$117	$45.9	$163	$28.5	$1.36	$29.9	$47.6	$2,125
ZD-5	$84	$45.9	$129	$24.7	$1.36	$26.0	$40.1	$1,788

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.
Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $65.0 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

Table 9-5
BREAKDOWN OF ESTIMATED COSTS
PROJECT ALTERNATIVE 2,
BRINE LIME TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000) Total	Water Cost(f) ($/ac-ft) Total
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total		
LB-1	$168	$54.9	$223	$19.9	$0.86	$20.8	$45.0	$2,008
LB-1A	$174	$54.9	$228	$20.8	$0.86	$21.6	$46.4	$2,073
LB-2	$163	$54.9	$218	$17.4	$0.86	$18.2	$41.9	$1,870
LB-3	$156	$54.9	$211	$18.6	$0.86	$19.4	$42.3	$1,888
LB-4	$157	$54.9	$212	$20.6	$0.86	$21.4	$44.4	$1,981
LB-4A	$179	$54.9	$234	$23.3	$0.86	$24.1	$49.5	$2,210
LB-5	$143	$54.9	$198	$19.1	$0.86	$20.0	$41.5	$1,853

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.
Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $65.0 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

Table 9-6
BREAKDOWN OF ESTIMATED COSTS
PROJECT ALTERNATIVE 2,
ZERO BRINE DISCHARGE TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/ac-ft)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
ZD-1	103.3	$40.8	$144	$25.3	$0.84	$26.1	$41.8	$1,866
ZD-1A	107.5	$40.8	$148	$26.0	$0.84	$26.8	$42.9	$1,916
ZD-2	94.5	$40.8	$135	$19.8	$0.84	$20.6	$35.3	$1,576
ZD-3	93.3	$40.8	$134	$24.2	$0.84	$25.1	$39.6	$1,769
ZD-4	94.1	$40.8	$135	$25.8	$0.84	$26.6	$41.3	$1,843
ZD-4A	$117	$40.8	$158	$28.5	$0.84	$29.4	$46.5	$2,077
ZD-5	83.5	$40.8	$124	$24.7	$0.84	$25.5	$39.0	$1,741

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.
Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $65.0 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

Table 9-7
BREAKDOWN OF ESTIMATED COSTS PROJECT ALTERNATIVE 4, BRINE LIME TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/ac-ft)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
LB-1	$185	$96.1	$281	$23.7	$2.38	$26.1	$56.6	$2,528
LB-1A	$191	$96.1	$287	$24.6	$2.38	$27.0	$58.1	$2,593
LB-2	$180	$96.1	$276	$21.2	$2.38	$23.6	$53.5	$2,390
LB-3	$173	$96.1	$269	$22.4	$2.38	$24.8	$54.0	$2,408
LB-4	$174	$96.1	$270	$24.4	$2.38	$26.7	$56.0	$2,501
LB-4A	$196	$96.1	$292	$27.1	$2.38	$29.4	$61.2	$2,730
LB-5	$161	$96.1	$257	$22.9	$2.38	$25.3	$53.2	$2,374

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life. Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $65.0 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

Table 9-8
BREAKDOWN OF ESTIMATED COSTS
PROJECT ALTERNATIVE 4,
ZERO BRINE DISCHARGE TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000) Treatment(d)	Capital Cost(c) ($1,000,000) Conveyance	Capital Cost(c) ($1,000,000) Total	O&M Cost ($1,000,000) Treatment(e)	O&M Cost ($1,000,000) Conveyance	O&M Cost ($1,000,000) Total	Annual Cost ($1,000,000) Total	Water Cost(f) ($/ac-ft) Total
ZD-1	$120	$86.6	$207	$29.1	$2.37	$31.5	$54.0	$2,409
ZD-1A	$125	$86.6	$211	$29.8	$2.37	$32.2	$55.1	$2,459
ZD-2	$112	$86.6	$198	$23.6	$2.37	$25.9	$47.5	$2,119
ZD-3	$110	$86.6	$197	$28.0	$2.37	$30.4	$51.8	$2,312
ZD-4	$111	$86.6	$198	$29.6	$2.37	$32.0	$53.5	$2,386
ZD-4A	$134	$86.6	$221	$32.4	$2.37	$34.7	$58.7	$2,620
ZD-5	$101	$86.6	$187	$28.5	$2.37	$30.8	$51.2	$2,284

(a) All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.
Alternatives are shown schematically in Figures 9-1 through 9-4.
(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards
(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.
(d) Treatment capital costs include outfall capital costs of $65.0 million for the alternatives with lime brine disposal.
(e) Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.
(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table Updated February 1993

Table 9-3
BREAKDOWN OF ESTIMATED COSTS
ALTERNATIVE 1,
BRINE LIME TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/AF)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
LB-1	$161	$46.1	$207	$20.5	$1.34	$21.9	$44.3	$1,979
LB-1A	$168	$46.1	$214	$21.6	$1.34	$22.9	$46.1	$2,058
LB-2	$156	$46.1	$202	$17.9	$1.34	$19.3	$41.2	$1,838
LB-3	$152	$46.1	$198	$19.1	$1.34	$20.4	$42.0	$1,874
LB-4	$173	$46.1	$219	$19.7	$1.34	$21.0	$44.7	$1,997
LB-4A	$196	$46.1	$242	$22.5	$1.34	$23.8	$50.1	$2,237
LB-5	$162	$46.1	$208	$17.9	$1.34	$19.2	$41.8	$1,865

(a) All estimated costs are in 1992 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.
Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $64.2 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $850,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table 9-4
BREAKDOWN OF ESTIMATED COSTS
ALTERNATIVE 1,
ZERO BRINE DISCHARGE TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/AF)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
ZD-1	$86	$45.4	$131	$30.0	$1.34	$31.3	$45.6	$2,035
ZD-1A	$91	$45.4	$136	$30.9	$1.34	$32.2	$47.0	$2,098
ZD-2	$84	$45.4	$130	$23.0	$1.34	$24.3	$38.4	$1,713
ZD-3	$79	$45.4	$124	$28.9	$1.34	$30.2	$43.7	$1,951
ZD-4	$95	$45.4	$140	$29.8	$1.34	$31.1	$46.4	$2,071
ZD-4A	$118	$45.4	$163	$32.5	$1.34	$33.8	$51.5	$2,300
ZD-5	$86	$45.4	$132	$28.4	$1.34	$29.7	$44.0	$1,965

(a) All estimated costs are in 1992 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life. Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $64.2 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $850,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table 9-5
BREAKDOWN OF ESTIMATED COSTS
ALTERNATIVE 2,
BRINE LIME TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/AF)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
LB-1	$161	$54.2	$215	$20.5	$0.85	$21.4	$44.7	$1,997
LB-1A	$168	$54.2	$222	$21.6	$0.85	$22.4	$46.5	$2,076
LB-2	$156	$54.2	$210	$17.9	$0.85	$18.8	$41.6	$1,856
LB-3	$152	$54.2	$207	$19.1	$0.85	$19.9	$42.4	$1,891
LB-4	$173	$54.2	$227	$19.7	$0.85	$20.5	$45.1	$2,014
LB-4A	$196	$54.2	$250	$22.5	$0.85	$23.3	$50.5	$2,254
LB-5	$162	$54.2	$216	$17.9	$0.85	$18.7	$42.2	$1,883

(a) All estimated costs are in 1992 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.
Alternatives are shown schematically in Figures 9-1 through 9-4.
(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards
(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.
(d) Treatment capital costs include outfall capital costs of $64.2 million for the alternatives with lime brine disposal.
(e) Treatment O&M costs include outfall O&M costs of $850,000 for alternatives with the lime brine disposal option.
(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table 9-6
BREAKDOWN OF ESTIMATED COSTS
ALTERNATIVE 2,
ZERO BRINE DISCHARGE TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/AF)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
ZD-1	85.8	$40.4	$126	$30.0	$0.83	$30.8	$44.5	$1,988
ZD-1A	91.0	$40.4	$131	$30.9	$0.83	$31.7	$46.0	$2,051
ZD-2	84.3	$40.4	$125	$23.0	$0.83	$23.8	$37.3	$1,666
ZD-3	78.8	$40.4	$119	$28.9	$0.83	$29.7	$42.6	$1,904
ZD-4	95.0	$40.4	$135	$29.8	$0.83	$30.6	$45.3	$2,024
ZD-4A	$118	$40.4	$158	$32.5	$0.83	$33.3	$50.5	$2,253
ZD-5	86.3	$40.4	$127	$28.4	$0.83	$29.2	$43.0	$1,918

(a) All estimated costs are in 1992 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life. Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $64.2 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $850,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Table 9-8
BREAKDOWN OF ESTIMATED COSTS
ALTERNATIVE 4,
ZERO BRINE DISCHARGE TREATMENT(a)

Treatment Alternative(b)	Capital Cost(c) ($1,000,000)			O&M Cost ($1,000,000)			Annual Cost ($1,000,000)	Water Cost(f) ($/AF)
	Treatment(d)	Conveyance	Total	Treatment(e)	Conveyance	Total	Total	Total
ZD-1	$95	$85.6	$180	$34.5	$2.35	$36.9	$56.5	$2,520
ZD-1A	$100	$85.6	$186	$35.4	$2.35	$37.7	$57.9	$2,583
ZD-2	$93	$85.6	$179	$27.5	$2.35	$29.8	$49.2	$2,198
ZD-3	$88	$85.6	$173	$33.4	$2.35	$35.7	$54.6	$2,436
ZD-4	$104	$85.6	$190	$34.3	$2.35	$36.7	$57.3	$2,556
ZD-4A	$127	$85.6	$212	$37.0	$2.35	$39.4	$62.4	$2,785
ZD-5	$95	$85.6	$181	$32.9	$2.35	$35.3	$54.9	$2,451

(a) All estimated costs are in 1992 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life.
Alternatives are shown schematically in Figures 9-1 through 9-4.

(b) Treatment Alternatives: LB = Lime Brine Treatment, ZD = Zero Brine Discharge Treatment
Treatment Alternatives 1A and 4A meet groundwater nondegradation standards
Treatment Alternatives 1, 2, 3, 4, 5 meet composite treatment standards

(c) Capital costs include a 20% allowance for engineering, legal, and administrative costs.

(d) Treatment capital costs include outfall capital costs of $64.2 million for the alternatives with lime brine disposal.

(e) Treatment O&M costs include outfall O&M costs of $850,000 for alternatives with the lime brine disposal option.

(f) Water costs are based on production of 20 mgd (22,400 ac-ft/yr).

Blue Ribbon Committee Comments

Mr. Lauer generally believed that the cost estimates were within a reasonable range based on comparison with other reclamation projects, considering the relatively higher costs associated with the Bay Area.

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Appendix A
Hydraulic Analysis of Reclaimed Water Recharge

Santa Clara Valley
Groundwater Model Project

Hydraulic Analysis of Reclaimed Water Recharge

Prepared for
City of San Jose
and
Santa Clara Valley Water District

by
CH2M HILL
July 31, 1992
SFO27295.LM.ZZ

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Section 1
Executive Summary

Section 1

Executive Summary

The feasibility of three alternatives to recharge reclaimed water into the Santa Clara Valley Groundwater Basin were analyzed:

- Construction of injection wells in the confined aquifer near the San Jose/ Santa Clara Water Pollution Control Plant (SJ/SC WPCP)
- Construction of injection wells in the Forebay Area (also referred to as the Recharge Zone)
- Use of the Coyote Creek Recharge Facility operated by the Santa Clara Valley Water District (SCVWD)

The results of the Confined Zone injection analysis suggest:

- Approximately 3 mgd of water could be recharged through 10 injection wells
- Thirteen existing wells would not satisfy the DHS criteria for minimum horizontal distance
- The maximum reclaimed water contribution to nearby wells would exceed the DHS criteria.

Results of the Forebay injection analysis suggest that:

- 25 mgd of water could be injected through 12 wells
- One existing well in the area would not satisfy the DHS minimum horizontal distance and minimum retention time (residence time or travel time) criteria
- Water pumped from wells downgradient of the injection wellfield would exceed the DHS maximum reclaimed water contribution criteria

Results of the Coyote Facility analysis suggest:

- The depth to groundwater beneath the Coyote Creek Recharge Facility is approximately 10 to 15 feet when operating at the current average spreading rate of 18 mgd

- Twenty-one existing wells would not satisfy the DHS minimum horizontal distance and minimum retention time criteria.

- Water pumped from wells downgradient of the Coyote Creek Recharge Facility would exceed the DHS maximum reclaimed water contribution criteria.

The results of all alternatives with respect to satisfying the proposed DHS criteria are summarized in Table 1-1.

The most significant uncertainty in the estimates presented in these analyses lies in the estimate of the transmissivity of the aquifer. The actual aquifer transmissivity at the potential injection sites may vary by plus or minus 50 percent. Since injection quantity is roughly proportional to the assumed transmissivity, the estimates of injection quantity may also vary by plus or minus 50 percent.

The greatest uncertainty in the surface spreading basin alternative also lies in the assumed aquifer properties. The velocity of groundwater near the spreading basins is directly proportional to the assumed aquifer hydraulic conductivity. Therefore, the 50 percent uncertainty in the assumed hydraulic conductivity will also exist in the estimates of reclaimed water retention time.

This memorandum is intended to be technical in nature. Political and economic issues, along with potential mitigation strategies to meet DHS criteria, will be presented in Chapter 3 of the Summary Background Report.

Table 1-1
Summary of Alternatives Evaluation

				Does Alternative Satisfy DHS Critieria For:					
Alternative	**Recharge Quantity (±50%)**	**Number of Injection Wells**	**Injection Well Spacing**	**Retention Time (50%)**	**Minimum Horizontal Distance**	**Maximum Reclaimed Water Contribution (±30%)**	**Depth to Groundwater (±50%)**	**Number of wells**	**Uses**
Confined Zone Injection	2.8 mgd	10	1,200-1,500 ft	Yes	No	No	--	13	U
Forebay Injection	25 mgd	12	2,000 ft	Yes	Yes	No	--	1	U
	30 mgd	16	4,000 ft	No	No	No	--	17	M,U
	35 mgd	20	6,000 ft	No	No	No	--	116	NE
Coyote Facility	18 mgd	N/A	N/A	No	No	No	Unknown–May Satisfy 10 ft Requirement	21	U

Notes: Error of Estimates Listed Below Each Category Where Applicable
-- = No depth to groundwater DHS criteria proposed for direct injection projects
NE = Not evaluated

Well Use Code:

M = Municipal
U = Unknown

Section 2
Introduction

Section 2
Introduction

This memorandum presents the results of analyses performed to investigate the feasibility of recharging reclaimed water into the potable aquifer of the Santa Clara Valley Groundwater Basin using injection wells and spreading basins (ponds). These analyses were performed to estimate the potential recharge capacities of several selected alternatives and to evaluate how well the alternatives would satisfy the proposed DHS criteria for the recharge of reclaimed municipal wastewater.

2.1 Scope of Analysis Performed

The scope of the analysis is to evaluate the recharge of reclaimed water to the local groundwater system at a feasibility study level of detail. A finite number of alternatives were investigated, and many other options exist for recharging reclaimed water into the Santa Clara Valley Groundwater Basin. Recharge evaluations were performed assuming steady-state hydraulic conditions and did not consider transient hydraulic behavior or the potential for chemical interactions between reclaimed water constituents and aquifer sediments.

2.2 Objectives

The analyses were undertaken to satisfy two major objectives. The first was to investigate the hydraulic conditions that would result from recharging varying quantities of reclaimed water into the potable aquifer using injection wells and spreading basins. Figure 2-1 shows the location of the two potential injection sites and one surface spreading facility where reclaimed water recharge was evaluated. The second objective was to evaluate how well these three recharge alternatives would satisfy the proposed DHS criteria for the recharge of reclaimed municipal wastewater. The minimum DHS criteria described in the March 2, 1992 draft regulations (unpublished) are listed below. The requirements listed are specific to the high-quality effluent that would result from the proposed treatment methods for this project.

- The minimum retention time (residence time or travel time) of reclaimed water in the potable aquifer is 12 months for injection projects and 6 months for spreading basin projects

- The maximum reclaimed water contribution to any domestic water supply well shall not exceed 50 percent

- The minimum horizontal distance between an area where reclaimed water is applied and a domestic water supply well shall be 2,000 feet for direct injection projects and 500 feet for spreading basin projects

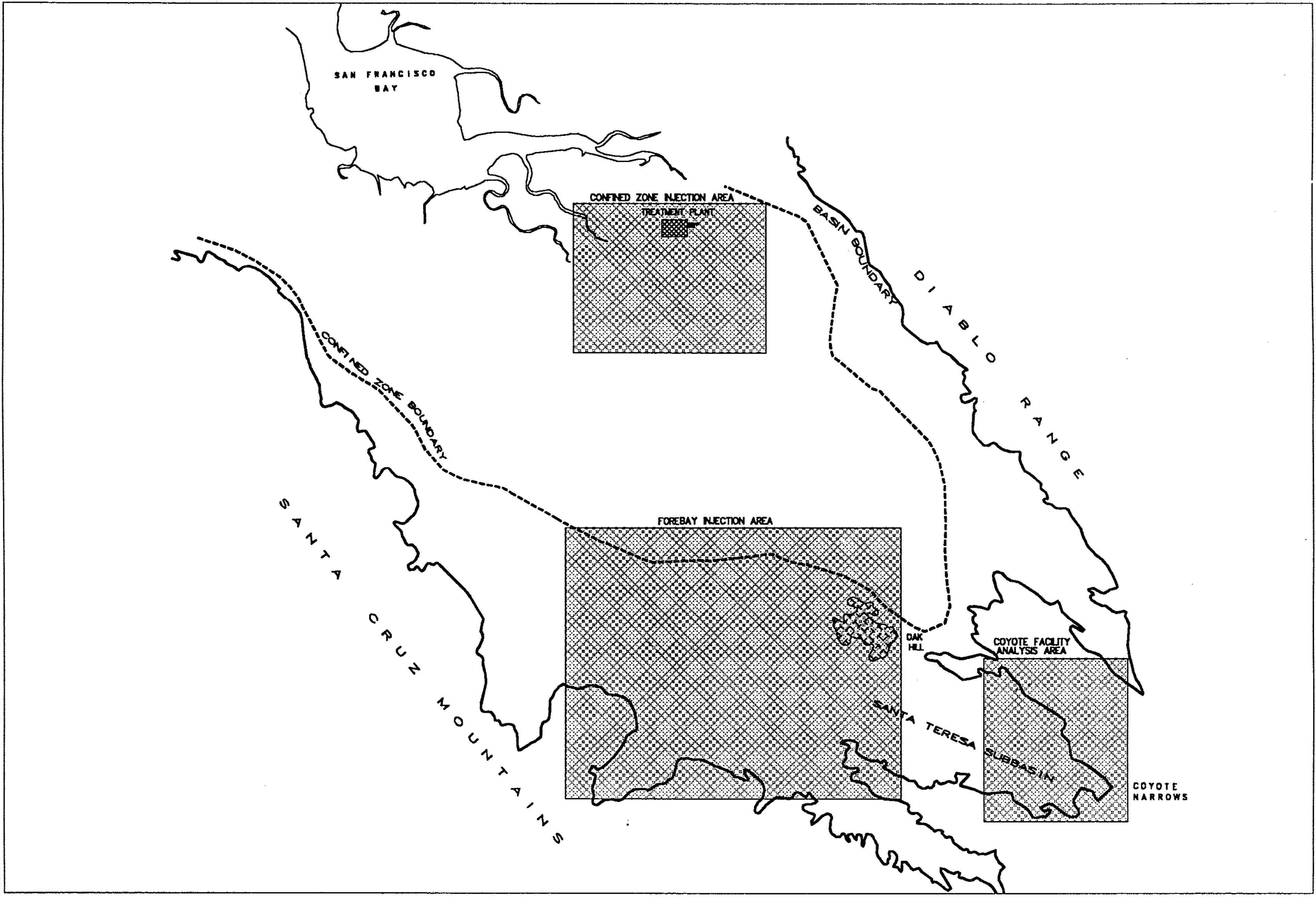


FIGURE 2-1
LOCATION OF RECHARGE SITE STUDY AREAS

- The minimum depth to groundwater beneath a spreading basin is 10 feet where the initial percolative capacity is less than 0.2 in/min and 20 feet where the initial percolative capacity is less than 0.3 in/min

Section 3
Approach

Section 3
Approach

3.1 Conceptual Model

The first step in evaluating potential recharge sites was to define the stratigraphy present at the site and the hydraulic properties of the stratigraphic units. The thickness of each unit, the horizontal and vertical hydraulic conductivities of each unit, and the vertical leakage between adjacent units were estimated. These estimates were based on information from several sources: the basinwide model developed by CH2M HILL (1992a and b), field investigations including aquifer tests conducted at groundwater contamination sites (Woodward Clyde, 1988), and previous studies in the area conducted by the California Department of Water Resources and the United States Geological Survey (CDWR, 1975; Johnson et al, 1968). For aquifer materials, assumed horizontal hydraulic conductivity values ranged from 2.5 to 200 feet per day, and vertical hydraulic conductivities ranged from 0.01 to 20 ft/day. For aquitard materials, the assumed horizontal hydraulic conductivity was 0.05 ft/day, and the vertical hydraulic conductivity was assumed to be 0.001 ft/day.

3.2 Hydraulic Head Distributions

The stratigraphic and hydraulic information was used as input to a steady-state, analytical, multi-layer computer model (Hunt, 1985). This model simulates the hydraulic head at each grid point in a multi-aquifer system by superimposing the drawdown or head rise from each pumping or injection well in the system. These models included pumping by both proposed and existing wells. The output from this model includes the hydraulic head distribution for each layer of the system, and the drawdown or head rise at each well in the system. A limitation of this approach is that it assumes an aquifer with unlimited horizontal extent and homogeneous aquifer properties in the horizontal and vertical directions. Because site conditions do not meet these assumptions, some uncertainty is introduced into the accuracy of the estimates presented.

3.3 Groundwater Flowlines

The hydraulic head output from the groundwater model was used to calculate the groundwater flowlines in each model layer using the computer program GWPATH (Shafer, 1987). This program calculates flowlines starting at any source or sink, and estimates the travel time for the groundwater to reach discrete points along the flow path. Travel time calculations depend on an estimate of the transport porosity of the aquifer. Transport porosity is defined as the porosity available for the transport of fluids through porous media, and excludes dead end pore space and other voids that do not provide pathways for flow. In this analysis, a value of 0.2 was used for the transport porosity of the aquifer.

3.4 Reclaimed Water Velocity/Retention Time

The retention time of the reclaimed water in the aquifer was also calculated using the following form of Darcy's Law:

$$V = KI/\Theta$$

Where:

K = Horizontal hydraulic conductivity of the aquifer (ft/day)
I = Horizontal hydraulic gradient (ft/ft)
Θ = Transport porosity of the aquifer (vol/vol)
V = Reclaimed water velocity (ft/day)

Using this equation, the reclaimed water velocity may be calculated at any point in the flow field. Retention time in the aquifer was estimated based on the distance from the recharge point to the closest point of extraction.

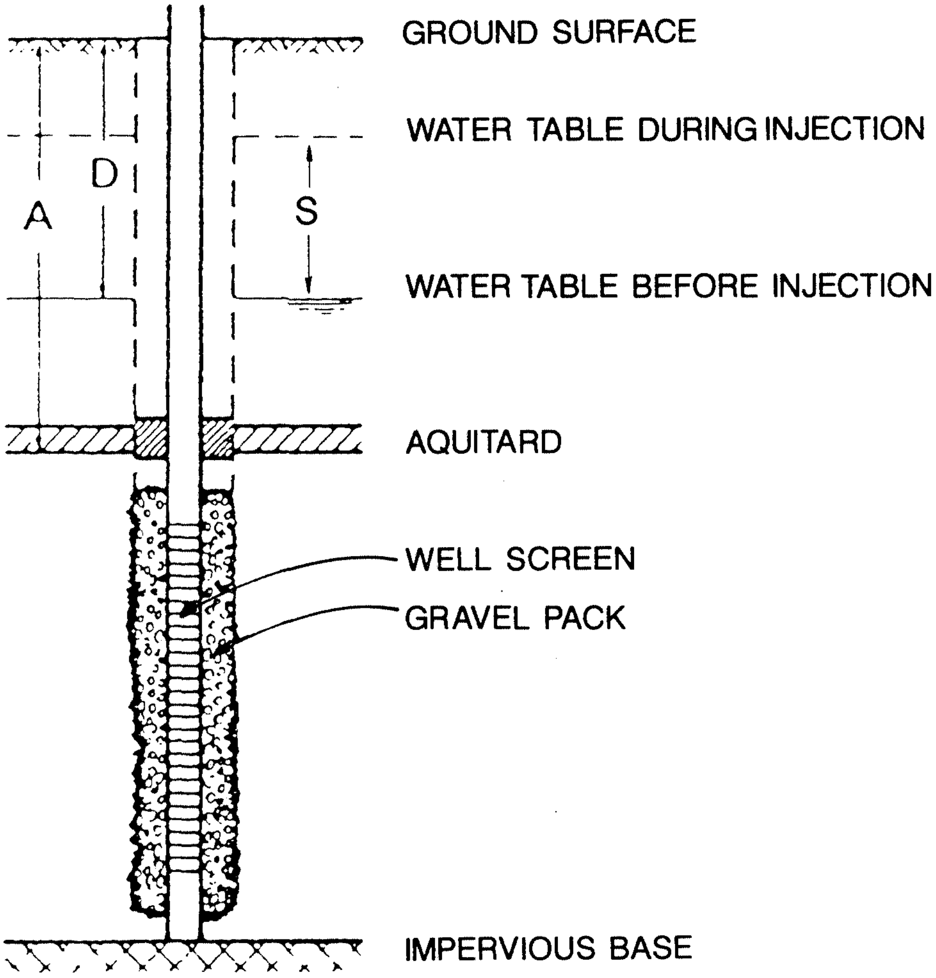
3.5 Maximum Reclaimed Water Contribution to Wells

To estimate the maximum contribution of reclaimed water to domestic water supply wells downgradient of a recharge site, a water balance approach was used. As reclaimed water is injected into the target aquifer, a head gradient develops that forces water upward and downward into adjacent stratigraphic units. The magnitude of the leakage between layers was calculated based on the vertical hydraulic conductivity of the layers, the vertical hydraulic head gradient that develops in response to injection, and the area through which leakage occurs. Once leakage quantity was estimated, the quantity of reclaimed water remaining in the target aquifer was also calculated. Finally, the extent of dilution that occurs was calculated by estimating the quantity of native groundwater that moves into the recharge area from upgradient sources, and assuming complete mixing between the recharged water and native groundwater. One of the limitations with this approach is that it assumes that the native groundwater moving from upgradient sources completely mixes with the recharged water. In reality, a range of reclaimed water concentrations could develop in the aquifer because of incomplete mixing.

3.6 Injection Recharge Capacity

To estimate the quantity of reclaimed water that can be injected at a potential recharge site, it was necessary to establish a criterion by which an aquifer would be considered to be at capacity. This criterion was different depending on whether the target aquifer for injection was confined or unconfined. For an unconfined aquifer, the criterion used to determine aquifer capacity was a minimum depth to water. As water levels in an aquifer rise in response to injection, significant damage may occur when groundwater levels approach the ground surface (eg. flooded basements, etc.). For the purpose of this evaluation, the minimum acceptable depth to water was defined to be 20 feet below ground surface.

For a confined aquifer, the aquifer capacity was defined by the maximum wellhead pressure that the formation could withstand. Water injected into a confined aquifer is stored as increased pore pressure as opposed to a rising water table. As a result, there is a maximum additional pore pressure that a formation can tolerate before excess pressure begins to fracture the confining sediments and the injected water moves into the overlying soils. A formation can withstand a pressure equal to approximately 22 percent of the difference between the depth to the confining layer and the pre-injection depth to water (Huisman and Olsthoorn, 1983). This relationship, shown graphically on Figure 3-1, was used to define the recharge capacity of the confined aquifer near the SJ/SC WPCP.



MAXIMUM ALLOWABLE HEAD RISE DURING INJECTION(S) $\simeq$ 0.22 * (A-D)

SOURCE: Huisman and Olsthoorn, 1983

NOTE: NOT TO SCALE

FIGURE 3-1
MAXIMUM ALLOWABLE HEAD RISE
DURING INJECTION INTO A CONFINED AQUIFER

Section 4
Results

Section 4
Results

4.1 Confined Zone Injection Alternative

4.1.1 Alternative Description

In the Confined Zone injection alternative, reclaimed water is injected into the Lower Aquifer Zone near the SJ/SC WPCP. The potential advantage of this alternative is that it would not require the construction of a lengthy conveyance pipeline from the SJ/SC WPCP to the point of recharge. The target aquifer for this alternative lies at a depth of 190 to 490 feet.

4.1.2 Simulation Assumptions and Limitations

The assumed site stratigraphy and hydraulic properties are shown on Figure 4-1. This project would inject into the Lower Aquifer Zone. The stratigraphy and the hydraulic properties are based on the basinwide model developed by CH2M HILL (1992b). The locations and pumping rates of existing wells are from the SCVWD database (SCVWD, 1992). The pumping rates of existing wells used for the simulations are annual averages from 1990. The regional gradient is based on SCVWD groundwater elevation maps for 1989 (SCVWD, 1989). The hydraulic properties assumptions are the greatest source of uncertainty in this set of calculations. The quantity of water that can be injected into an aquifer depends almost linearly on the transmissivity. In other words, if the assumed transmissivity of an aquifer is doubled, the estimated quantity of water that can be injected with an equal head rise in the aquifer would also approximately double. It is possible that in some portions of the modeled area, the assumed transmissivities may deviate from the true values by as much as 50 percent. This suggests a potential error in the recharge quantity estimate of about plus or minus 50 percent.

4.1.3 Recharge Quantity

Approximately 2.8 mgd of water could be injected into the Lower Aquifer Zone near the SJ/SC WPCP through an injection wellfield containing 10 wells with a well spacing of approximately 1,200 to 1,500 feet. The quantity of injected water this aquifer could accept is limited because the aquifer near the SJ/SC WPCP is currently "full," i.e., the potentiometric head in the Lower Aquifer Zone is near the ground surface. Injecting water at rates greater than 2.8 mgd could increase wellhead pressures above the threshold value suggested by Huisman and Olsthorn, (1983) (See Section 3.5). Slightly higher quantities of water could be injected with a larger number of wells, but the size of the wellfield required would increase rapidly. The injection and pumping well locations near the SJ/SC WPCP are shown on Figure 4-2 along with the hydraulic head distribution in the Lower Aquifer Zone that would result from the assumed rates of injection.

Confined Zone Injection Alternative
Stratigraphic Section

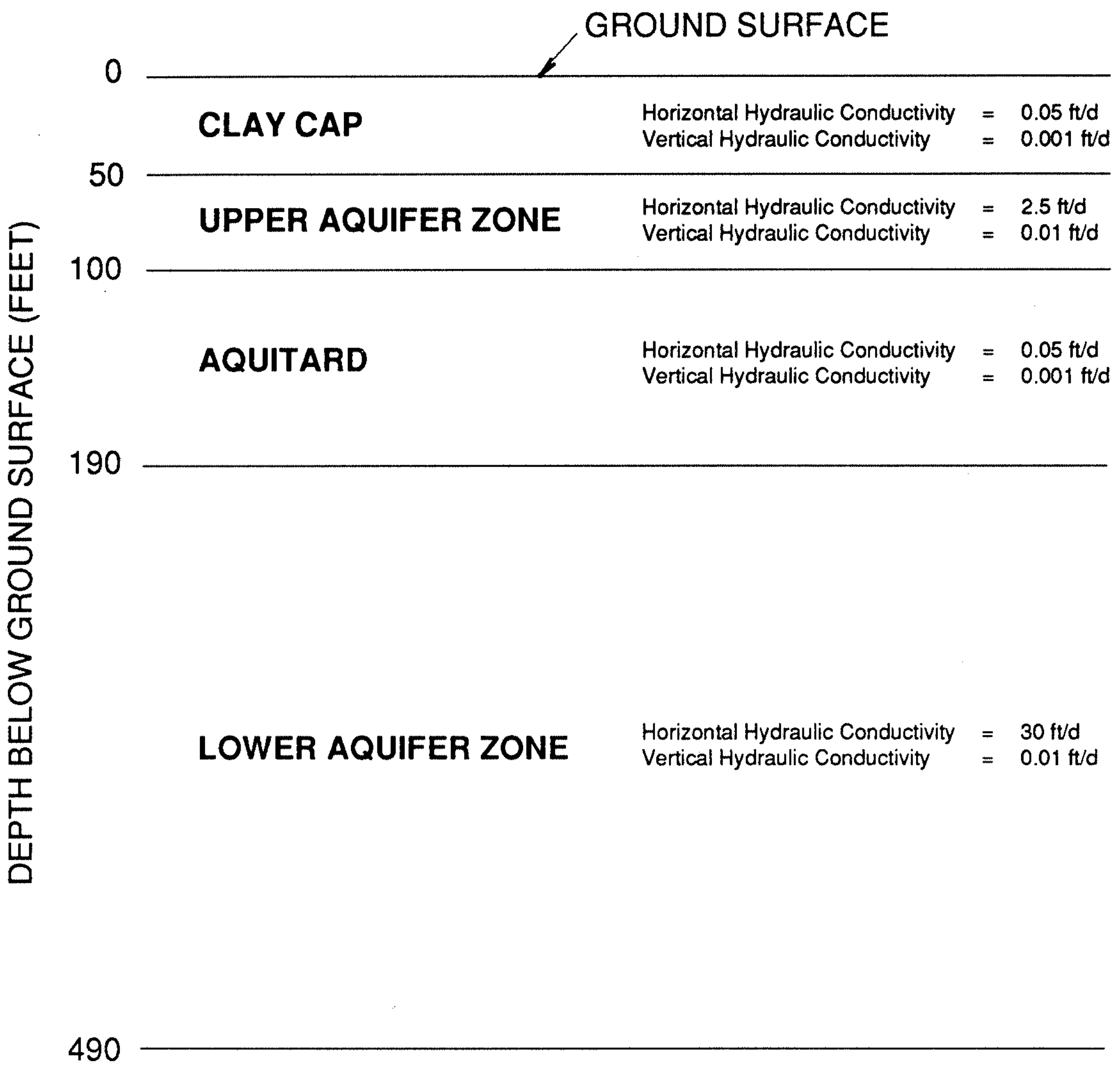
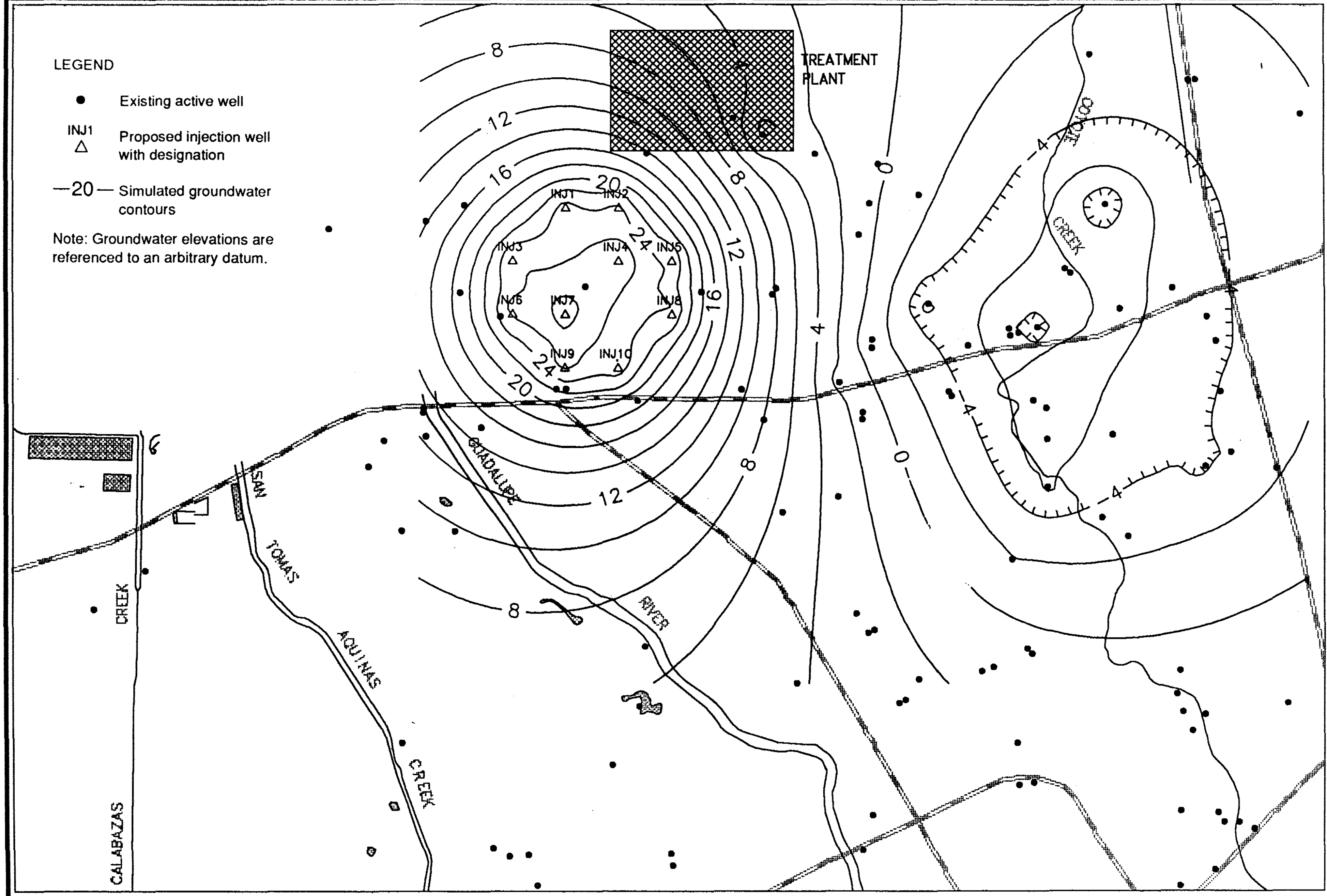

GROUND SURFACE
0
50
100
190
490
DEPTH BELOW GROUND SURFACE (FEET)
CLAY CAP
Horizontal Hydraulic Conductivity = 0.05 ft/d
Vertical Hydraulic Conductivity = 0.001 ft/d
UPPER AQUIFER ZONE
Horizontal Hydraulic Conductivity = 2.5 ft/d
Vertical Hydraulic Conductivity = 0.01 ft/d
AQUITARD
Horizontal Hydraulic Conductivity = 0.05 ft/d
Vertical Hydraulic Conductivity = 0.001 ft/d
LOWER AQUIFER ZONE
Horizontal Hydraulic Conductivity = 30 ft/d
Vertical Hydraulic Conductivity = 0.01 ft/d

FIGURE 4-1

STRATIGRAPHIC SECTION

CONFINED ZONE INJECTION ALTERNATIVE



0 1250 2500 5000

FEET

FIGURE 4-2
HYDRAULIC HEAD DISTRIBUTION IN LOWER AQUIFER ZONE, CONFINED ZONE INJECTION ALTERNATIVE

CH2M HILL

LM4-2.AML SFO27295.LM

July 22, 1992

4.1.4 Reclaimed Water Velocity/Retention Time

The water injected in the major aquifer near the SJ/SC WPCP would travel toward nearby wells at an average rate of approximately 350 feet per year. This estimate is based on an assumed transport porosity of 0.2. The flowlines of the water moving away from the injection wells through the Lower Aquifer Zone are shown on Figure 4-3. Groundwater velocities would vary across the site as a function of the magnitude of the hydraulic gradient at a specific location. The highest velocities of approximately 500 feet per year occur at the perimeter of the injection wellfield. The retention time contours in the Lower Aquifer Zone for recharged water moving away from the injection wellfield are shown on Figure 4-4. These contours account for the decreasing groundwater velocity as water moves away from the injection wells. Results indicate that six wells are located within the 12-month contour of minimum retention time. Therefore, these wells do not satisfy the DHS minimum retention time requirement.

4.1.5 Maximum Reclaimed Water Contribution

Groundwater pumped from wells located near the SJ/SC WPCP would not meet the DHS requirement of 50 percent dilution; the water pumped would consist of nearly 100 percent injected water. Several factors limit the dilution of the injected water at this location, the most significant being the presence of an extensive aquitard that prevents recharge from reaching the Lower Aquifer Zone. Another contributing factor is the shallow horizontal hydraulic gradient in the area that limits dilution from upgradient sources. Simulations suggest that water being pumped from domestic supply wells would not satisfy the 50 percent maximum reclaimed water contribution requirement.

4.1.6 Assessment of Nearby Well Locations

Records indicate that 13 wells lie within the minimum horizontal distance requirement of 2,000 feet of the proposed injection wellfield. This set of wells includes six wells referred to in Section 4.1.4. The designations of these wells are shown in Table 4-1. The SCVWD database lists seven of these wells as producing approximately 26 acre-feet per month in 1990. Data were available for the remaining six wells.

4.2 Forebay Injection Alternative

4.2.1 Alternative Description

Evaluation of the Forebay injection alternative addresses the feasibility of recharging reclaimed water in the unconfined aquifer of the Forebay. The general area used for analysis was selected based on a cursory review of well density and unsaturated zone thickness available for water-level rise. Pumping from retailer wells was neglected in

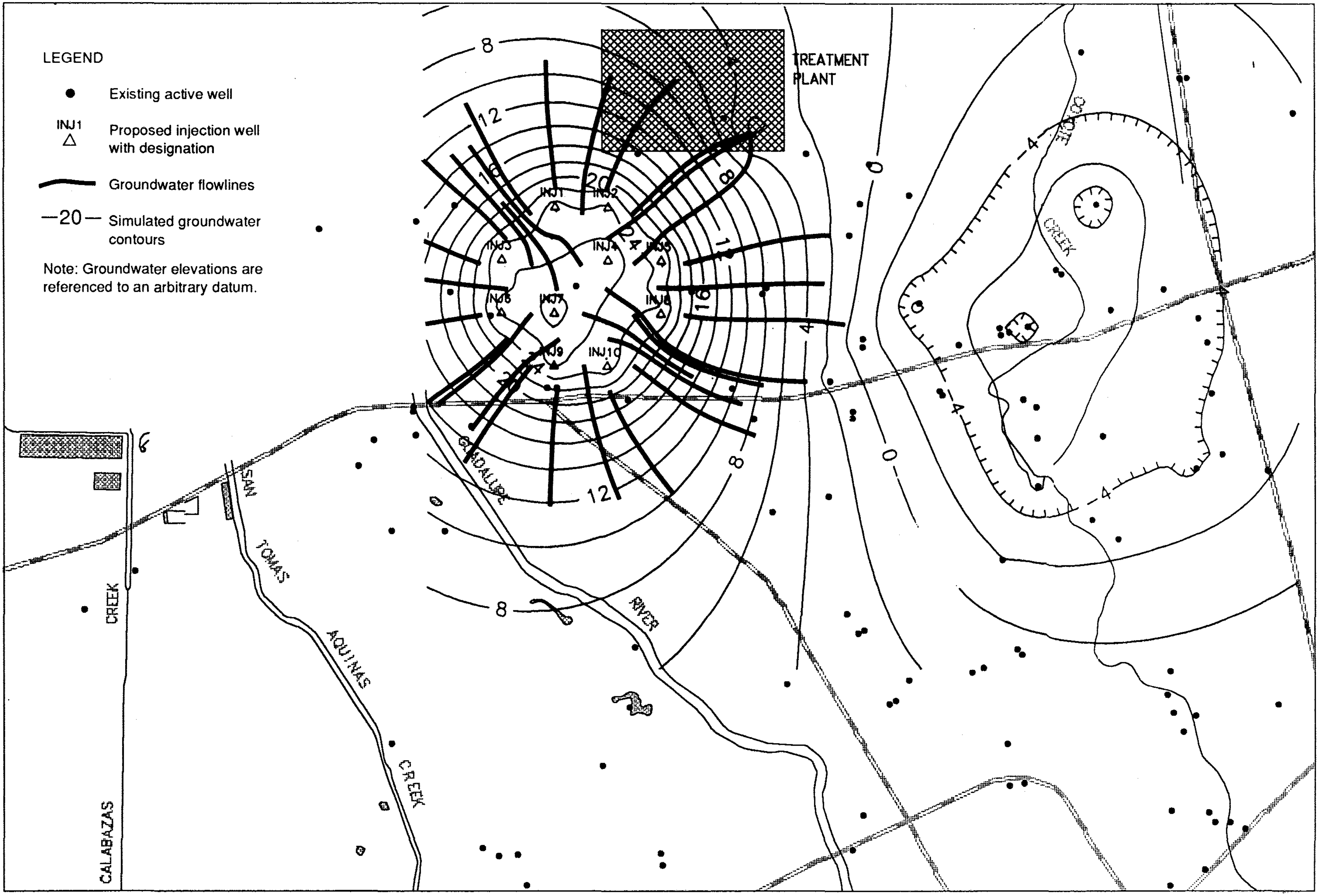


FIGURE 4-3
HYDRAULIC HEAD DISTRIBUTION AND GROUNDWATER FLOWLINES
IN THE LOWER AQUIFER ZONE, CONFINED ZONE INJECTION ALTERNATIVE

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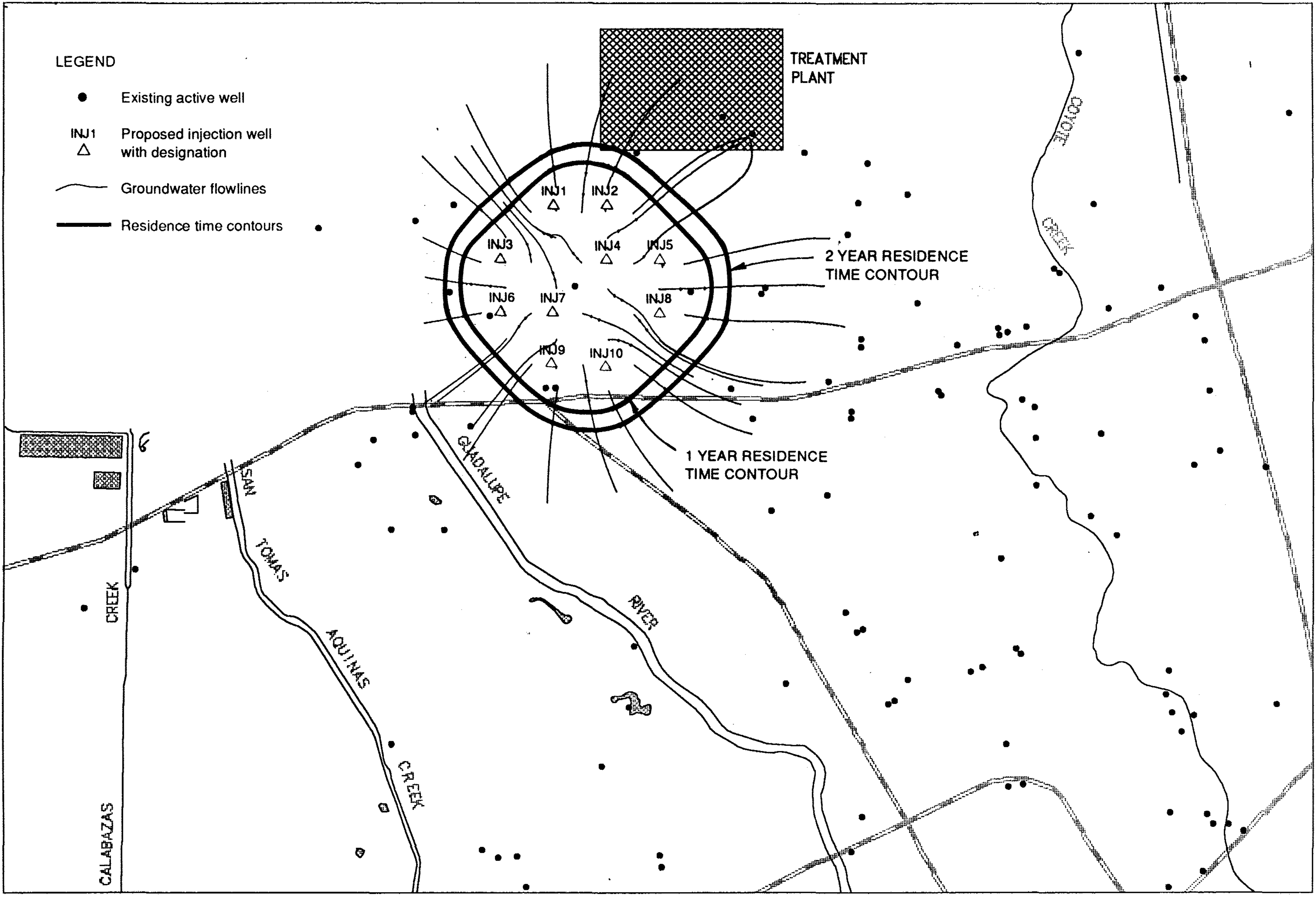

FIGURE 4-4
WELL LOCATIONS AND 1-YEAR AND 2-YEAR TRAVEL TIME CONTOURS FOR INJECTED WATER

CH2M HILL

LM4-4.AML SFO27295.LM

July 22, 1992

Table 4-1
Well Designations of Wells That Do Not Satisfy the DHS Minimum Horizontal Distance and Minimum Retention Time Criteria

Confined Zone Injection Alternative
06S1W10E03
06S1W10D01
06S1W10M01
06S1W10L03
06S1W10G03
06S1W10A01
06S1W10H01
06S1W11E01
06S1W11M01
06S1W11N02
06S1W10R03
06S1W10P02
06S1W10P03
Forebay Injection Alternative—25 MGD Case
08S1W12J01
Coyote Facility Analysis
08S2E17J04
08S2E16M01
08S2E16E11
08S2E08L03
08S2E08F01
08S2E08L02
08S2E08F04
08S2E08G01

Continued

Table 4-1
Well Designations of Wells That Do Not Satisfy the DHS Minimum Horizontal Distance and Minimum Retention Time Criteria

08S2E08F02
08S2E08F03
08S2E08C03
08S2E08C05
08S2E08D01
08S2E08D07
08S2E08D03
08S2E08D03[a]
08S2E07H04
08S2E07H05
08S2E07A03
08S2E07G01
08S2E08E02

Notes:

[a] SCVWD database contains two wells at different locations, both with the identifier 08S2E08D03

this analysis because it was developed as a generic Forebay injection alternative and no specific wellfield site was selected. This alternative consists of a wellfield injecting reclaimed water into the potable aquifer at one Forebay location (Figure 2-1). Many other potential strategies and recharge locations exist for injection into the Forebay Aquifer.

4.2.2 Simulation Assumptions and Limitations

The assumed stratigraphy and hydraulic properties used in the Forebay injection alternative evaluation are shown on Figure 4-5. While the hydraulic properties are assumed to be uniform with depth, the profile is separated into three layers to simulate water injection into Layer 2 where most of the surrounding wells are screened (100 to 400 feet below ground surface). The horizontal hydraulic conductivity values are consistent with the basinwide model. The regional gradient used in the simulations (0.0075 ft/ft) is consistent with groundwater contour maps developed by the SCVWD for the spring and fall of 1989 (SCVWD, 1989).

As in the Confined Zone alternative, the greatest uncertainty in these calculations lies in the assumed transmissivity of the aquifer. Given the geologic setting of the site, it is reasonable to assume that the transmissivity may vary by a factor of two at any site location, and this variability could significantly affect the performance of the injection wellfield. For example, if the transmissivity of the injected aquifer is half of what is assumed for the analysis, the quantity of water injected will be about half of the estimated amount. Any effects of the surface spreading facilities located near this potential injection site were not considered in this analysis.

4.2.3 Recharge Quantity

The results of the simulations suggest that approximately 25 mgd of water can be injected into the forebay aquifer through a wellfield containing 12 wells at a 2,000-foot well spacing. The injection well locations and the simulated hydraulic head distribution in Layer 2 in response to injection are shown on Figure 4-6. After injection of 25 mgd of water, groundwater elevations will rise approximately 65 feet in the vicinity of the injection wellfield, resulting in a minimum depth to groundwater of about 20 feet. Larger quantities of water could be injected using a larger wellfield, although interference between wells limits the benefit of adding additional wells at the wellfield's perimeter. For example, to inject 30 mgd requires 16 wells at a 4,000-foot well spacing and to inject 35 mgd requires 20 wells at a 6,000-foot well spacing. Alternatively, greater injection quantities could likely be achieved with several smaller wellfields located throughout the Forebay Area.

4.2.4 Reclaimed Water Velocity/Retention Time

The injected water will travel downgradient from the wellfield at a rate of approximately 1,300 feet per year. The predicted travel paths away from the wellfield

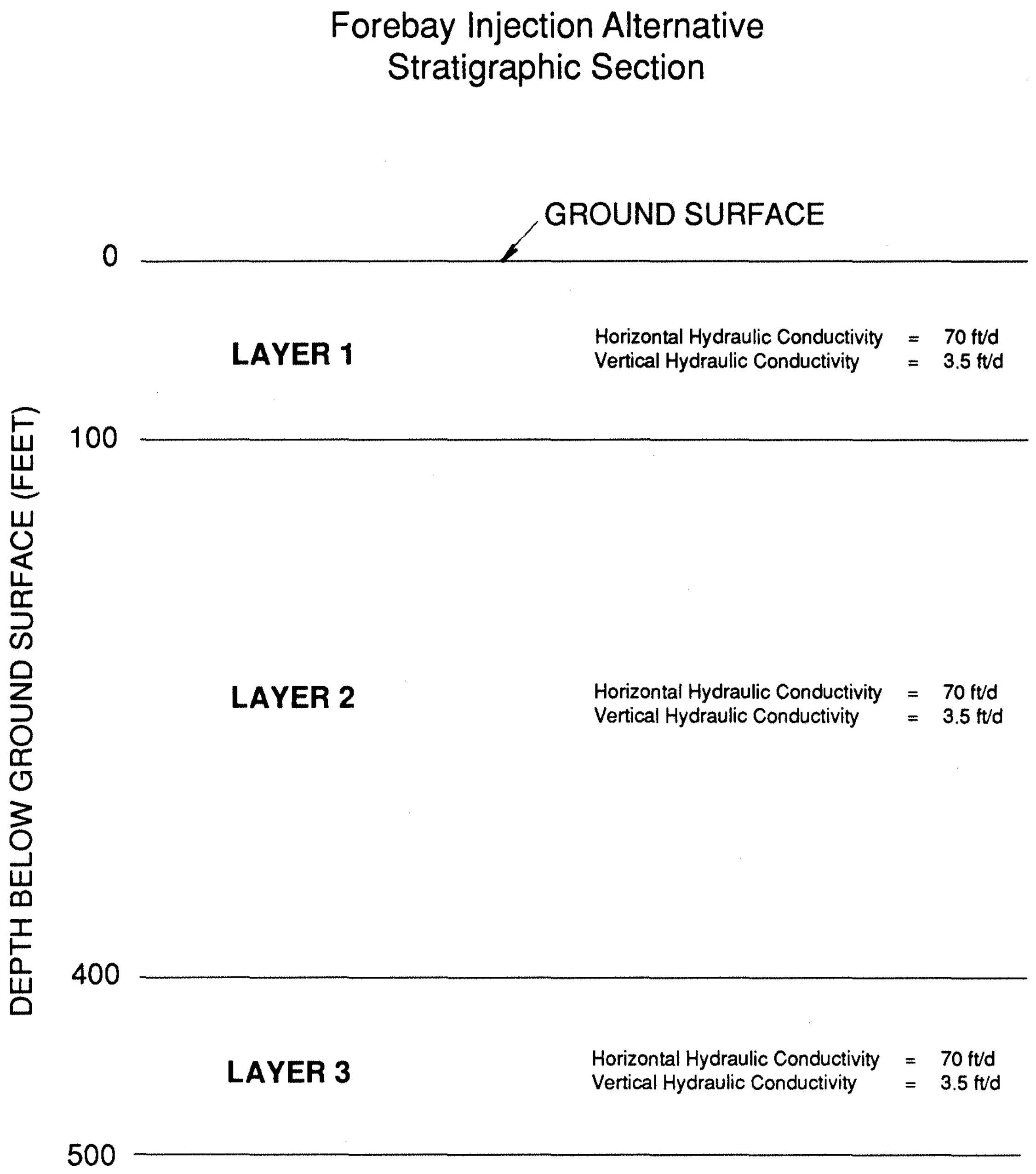
Forebay Injection Alternative
Stratigraphic Section
GROUND SURFACE
0
100
400
500
DEPTH BELOW GROUND SURFACE (FEET)
LAYER 1
Horizontal Hydraulic Conductivity = 70 ft/d
Vertical Hydraulic Conductivity = 3.5 ft/d
LAYER 2
Horizontal Hydraulic Conductivity = 70 ft/d
Vertical Hydraulic Conductivity = 3.5 ft/d
LAYER 3
Horizontal Hydraulic Conductivity = 70 ft/d
Vertical Hydraulic Conductivity = 3.5 ft/d

FIGURE 4-5

STRATIGRAPHIC SECTION

FOREBAY INJECTION ALTERNATIVE

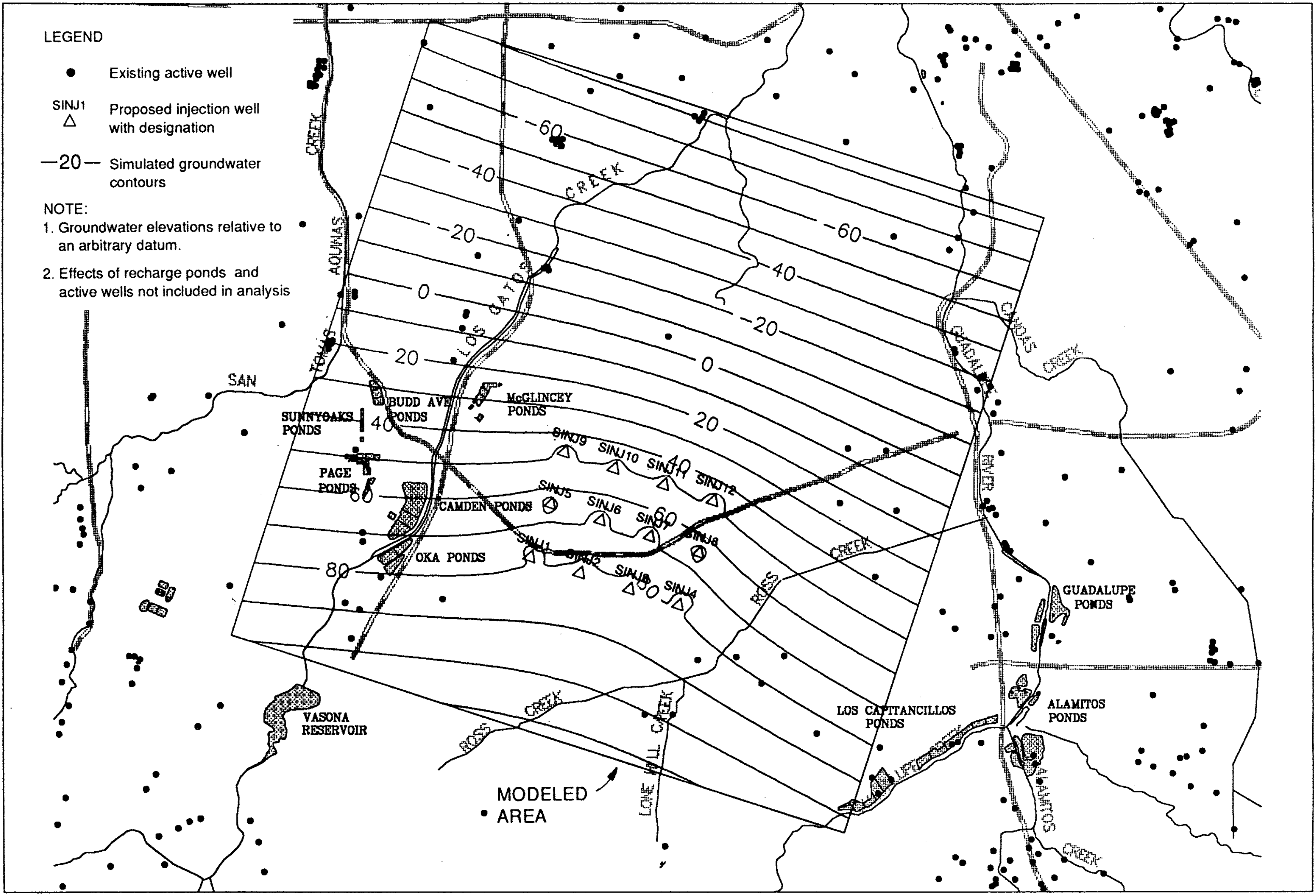

FIGURE 4-6

WELL LOCATIONS AND HYDRAULIC HEAD DISTRIBUTION IN LAYER 2 AFTER INJECTION, FOREBAY INJECTION ALTERNATIVE

CH2M HILL

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July 22, 1992

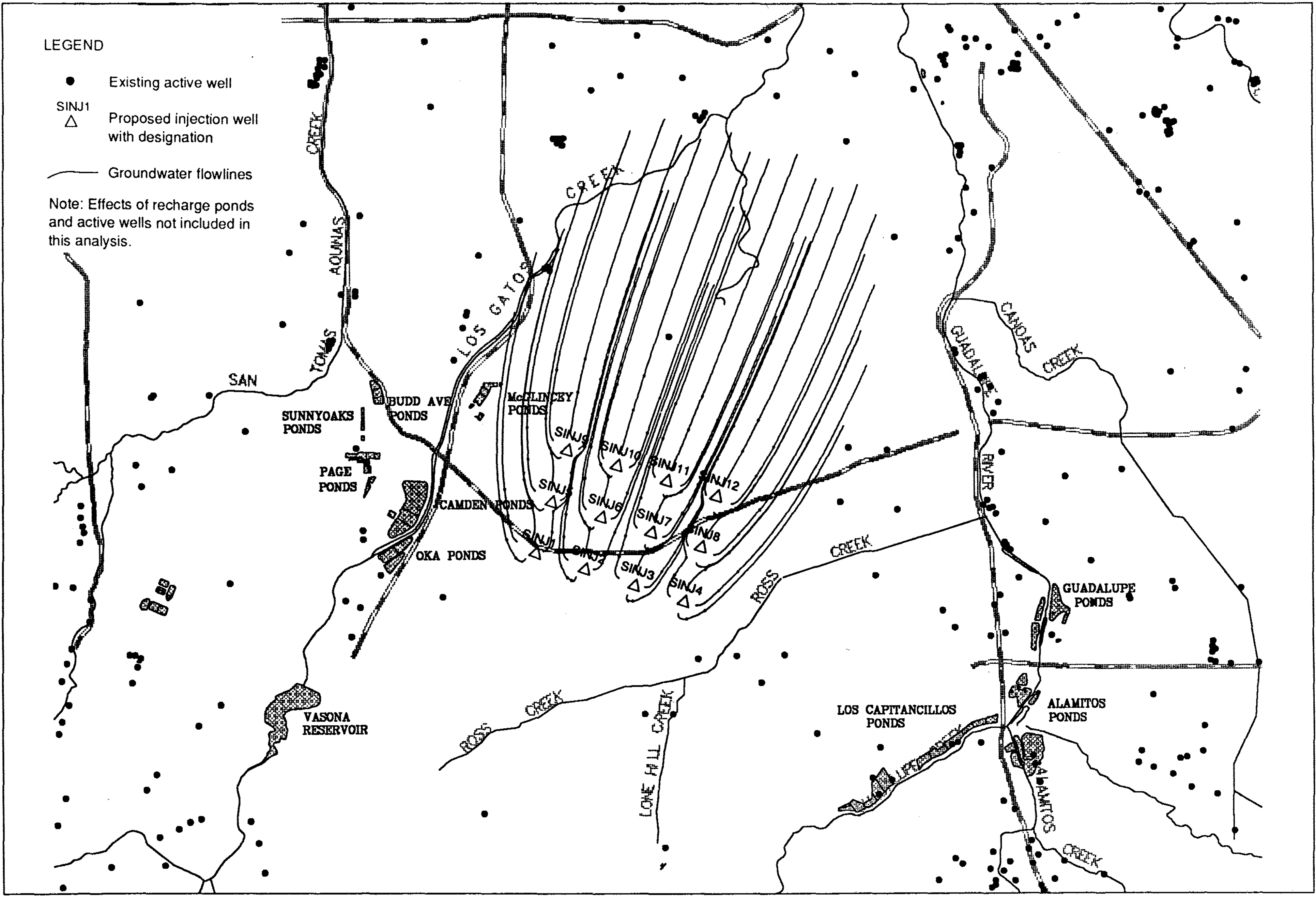


FIGURE 4-7
WELL LOCATIONS AND GROUNDWATER FLOWLINES IN LAYER 2, FOREBAY INJECTION ALTERNATIVE

CH2M HILL

LM4-7.AML SFO27295.LM

July 29, 1992

2,400 ft/yr at the wellfield perimeter, and drop to 1,300 feet per year as it travels downgradient. These groundwater velocities assume a transport porosity of 0.2. The retention time contours based on these groundwater velocities are shown on Figure 4-8. SCVWD records suggest that no active wells are located inside the required 12-month minimum retention time contour; therefore, the DHS minimum retention time requirement would be satisfied.

4.2.5 Maximum Reclaimed Water Contribution

In the simulation, the water that is injected into the Forebay Aquifer mixes with native groundwater moving from upgradient recharge areas. Water pumped from areas downgradient of the injection well field is estimated to be composed of approximately 75 percent injected water and 25 percent native groundwater (Figure 4-9); this does not satisfy the DHS 50 percent maximum reclaimed water contribution requirement if 100 percent reclaimed water is injected.

4.2.6 Assessment of Nearby Well Locations

According to SCVWD records, 1 well lies within 2,000 feet of the simulated injection wellfield sited in the Forebay Area (Figure 4-6). Therefore, the DHS minimum horizontal distance requirement would not be satisfied for this well. The designation of this well is included in Table 4-1. The SCVWD database lists this well as producing an average of 0.0035 acre-feet per month during 1990.

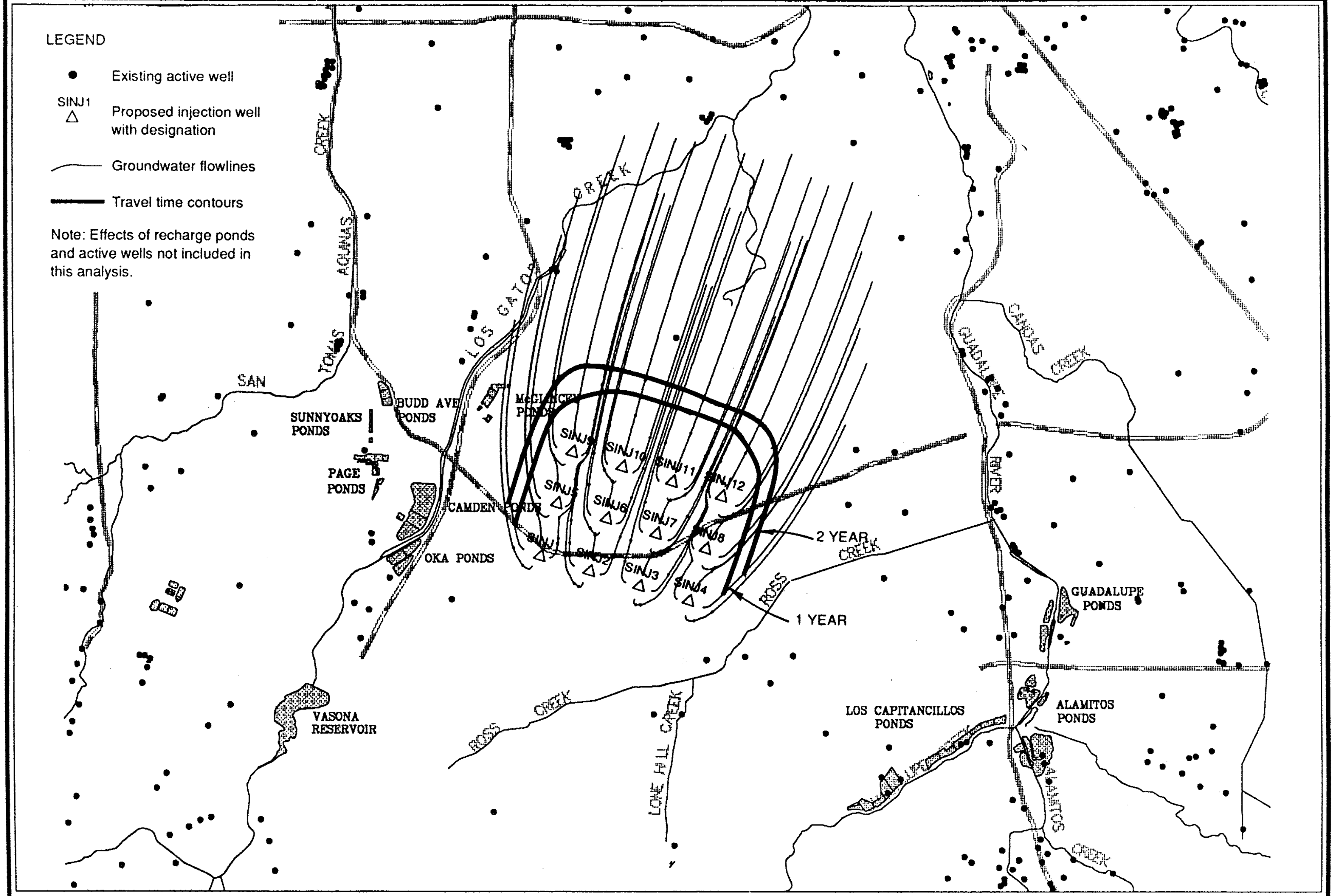
4.3 Surface Spreading Basin Alternative

4.3.1 Alternative Description

This alternative consists of using the existing Coyote Creek Recharge Facility to recharge reclaimed water into the aquifer at the site. The current spreading rate for this facility is approximately 18 mgd. After discussions with staff from the SCVWD and the City of San Jose, the Coyote Creek Recharge Facility was chosen for analysis since it is potentially a worst-case scenario because of high groundwater velocities at the site and the proximity of many retailer production wells.

4.3.2 Assumptions and Limitations Used in Coyote Creek Recharge Facility Simulations

The stratigraphy and assumed hydraulic properties used for the Coyote Creek Facility simulations are shown on Figure 4-10. The aquifer properties for this area are consistent with the basinwide model. The model layers were configured to allow spreading basin recharge to be applied into Layer 1 and groundwater to be pumped from retailer wells perforated in Layer 2. Well locations and pumping rates were obtained from the SCVWD database (SCVWD, 1992). Pumping quantities for 1989



0 2500 5000 10000

FEET

N

FIGURE 4-8

WELL LOCATIONS, GROUNDWATER FLOWLINES, AND 1-YEAR AND 2-YEAR TRAVEL TIME CONTOURS FOR INJECTED WATER, FOREBAY INJECTION ALTERNATIVE

CH2M HILL

July 23, 1992

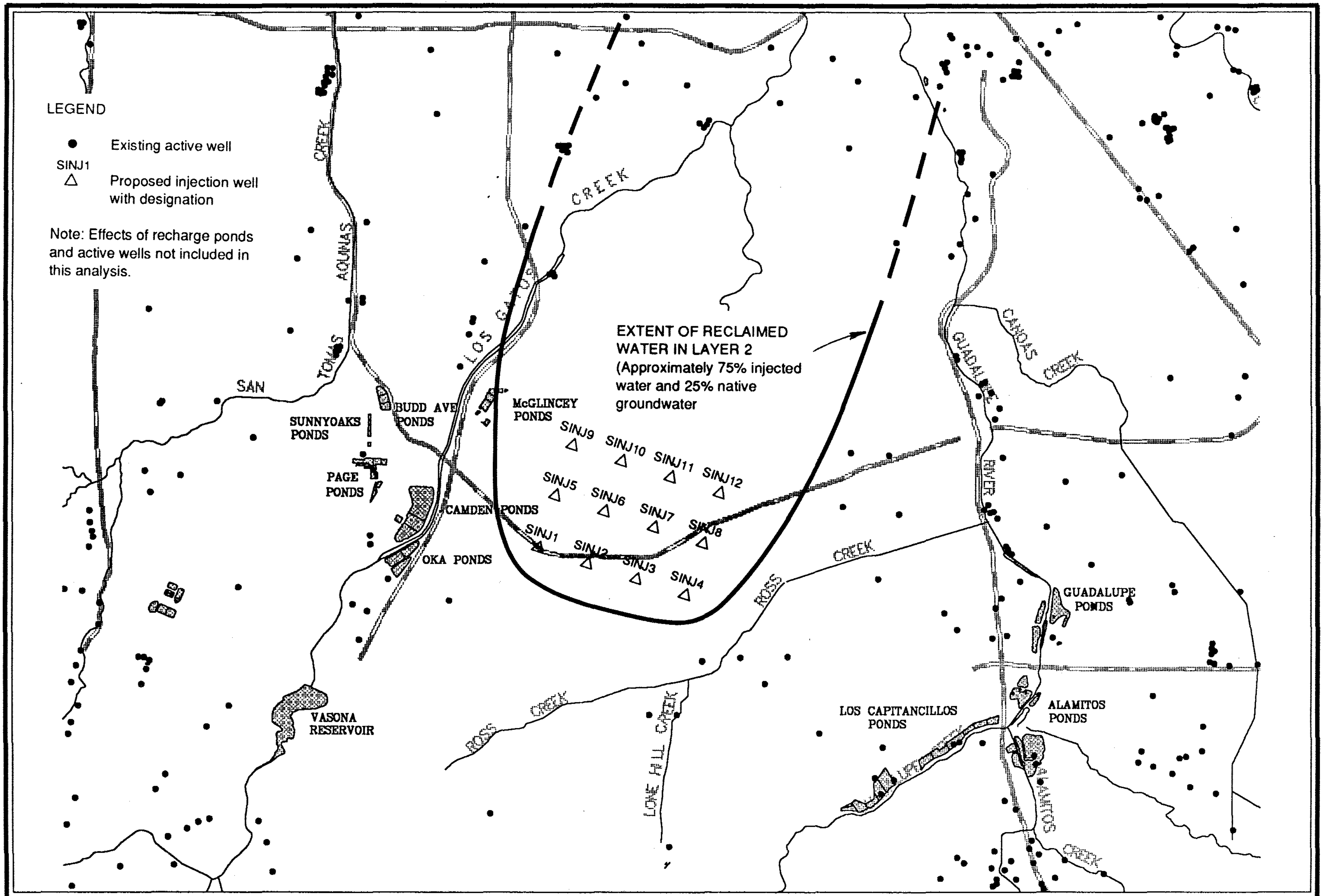


FIGURE 4-9
WELL LOCATIONS AND DISTRIBUTION OF INJECTED WATER
IN LAYER 2, FOREBAY INJECTION ALTERNATIVE

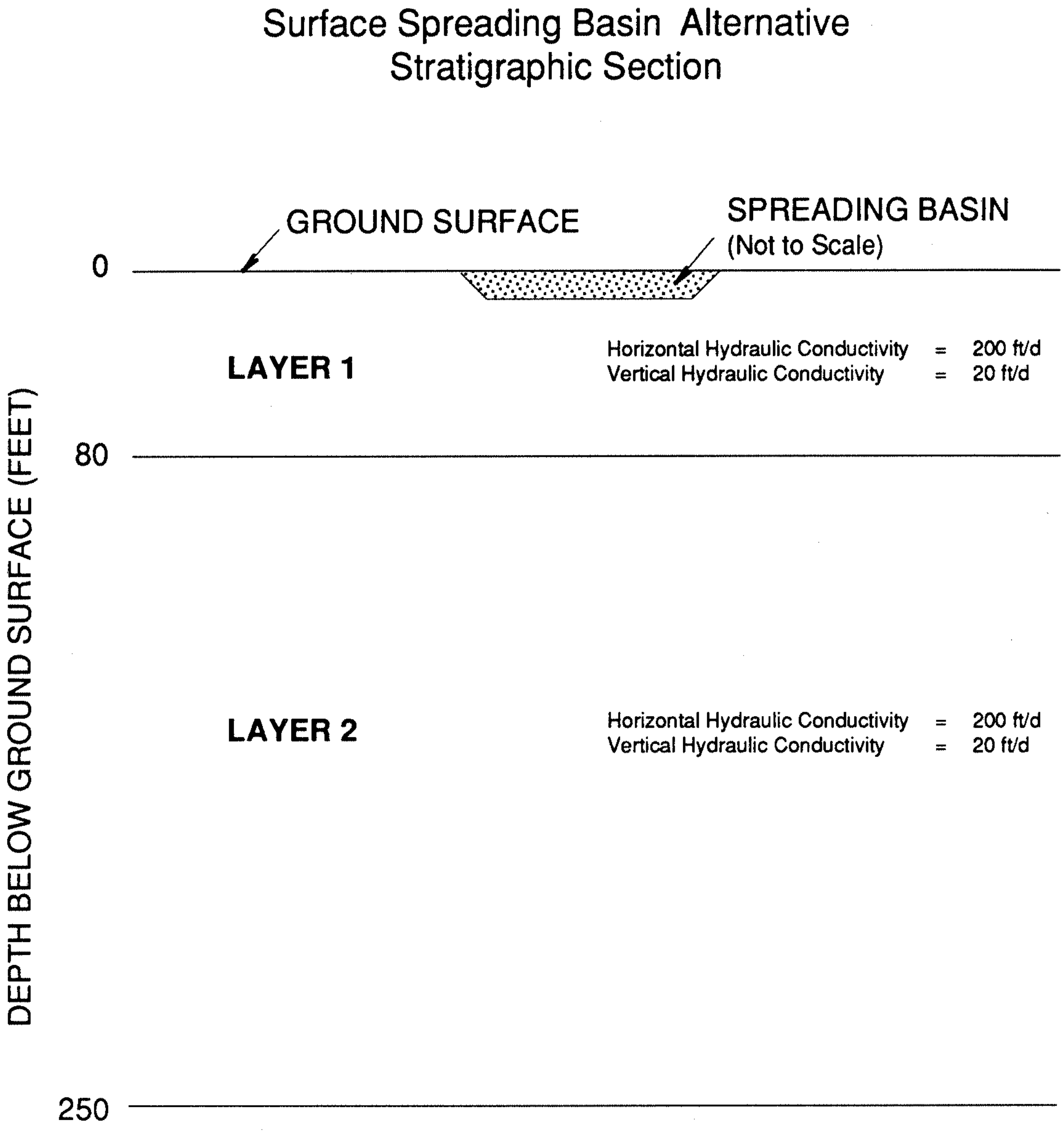

Surface Spreading Basin Alternative
Stratigraphic Section
GROUND SURFACE
SPREADING BASIN
(Not to Scale)
0
LAYER 1
Horizontal Hydraulic Conductivity = 200 ft/d
Vertical Hydraulic Conductivity = 20 ft/d
80
DEPTH BELOW GROUND SURFACE (FEET)
LAYER 2
Horizontal Hydraulic Conductivity = 200 ft/d
Vertical Hydraulic Conductivity = 20 ft/d
250

FIGURE 4-10

STRATIGRAPHIC SECTION

SURFACE SPREADING BASIN ALTERNATIVE

were totaled and converted into an average steady-state pumping rate. The regional gradients used in the simulations were calculated from simulated 1988 groundwater contour maps presented in previous studies of the area (Woodward-Clyde, 1988). Current, estimated, annual average spreading rates were used as recharge fluxes in the simulations. SCVWD staff indicate that the spreading basins are operating at near maximum capacity; thus, higher spreading rates were not considered (Iwamura, 1992).

Because the quantity of recharged water was not a variable in these simulations, the greatest uncertainty lies in the estimate of groundwater velocity, and, therefore, retention time. This estimate depends, in turn, on the assumed hydraulic conductivity of the aquifer and the estimate of transport porosity. A relatively high value of hydraulic conductivity (200 ft/day) was used in these calculations, so that the estimated groundwater velocity was conservative with respect to the DHS minimum retention time criteria. The estimate of transport porosity (0.2) is likely to vary by no more than 25 percent.

4.3.3 Depth to Groundwater

The recharge quantity used in the simulations is the annual average operating rate (18 mgd). Figure 4-11 presents the simulated hydraulic head distribution near the spreading basins. The potential to recharge quantities larger than current rates seems unlikely based on available data suggesting that groundwater is extremely shallow near the spreading basin facility. Even if the minimum depth to groundwater criteria is waived, once the groundwater elevation rises to the base of the spreading basins, no further increase in recharge rates is possible. Groundwater elevations measured in wells near the Coyote Creek Recharge Facility suggest that a maximum of approximately 10 to 15 feet of unsaturated zone may exist beneath the spreading basins. This suggests that the spreading basins of the Coyote Creek Recharge Facility may not meet the DHS minimum depth to groundwater requirement.

4.3.4 Reclaimed Water Velocity/Retention Time

Simulation results suggest that the estimated reclaimed water velocity will range from 2,400 to 3,200 feet per year. The higher values are seen near the Coyote Ponds located near Coyote Narrows. The calculated flow paths of the reclaimed water as it leaves the spreading basins are shown on Figure 4-12 as are the contours of reclaimed water retention time in the potable aquifer. Ten wells lie within the 6-month minimum retention time of the spreading basins as shown on Figure 4-12. The uses and approximate average annual pumping rates for these wells are listed in Table 4-1.

4.3.5 Maximum Reclaimed Water Contribution

The estimated percent of recharged water in the potable aquifer downgradient of the spreading basins is shown on Figure 4-13. The results show that water pumped from wells located downgradient of the Coyote Creek Recharge Facility would consist of

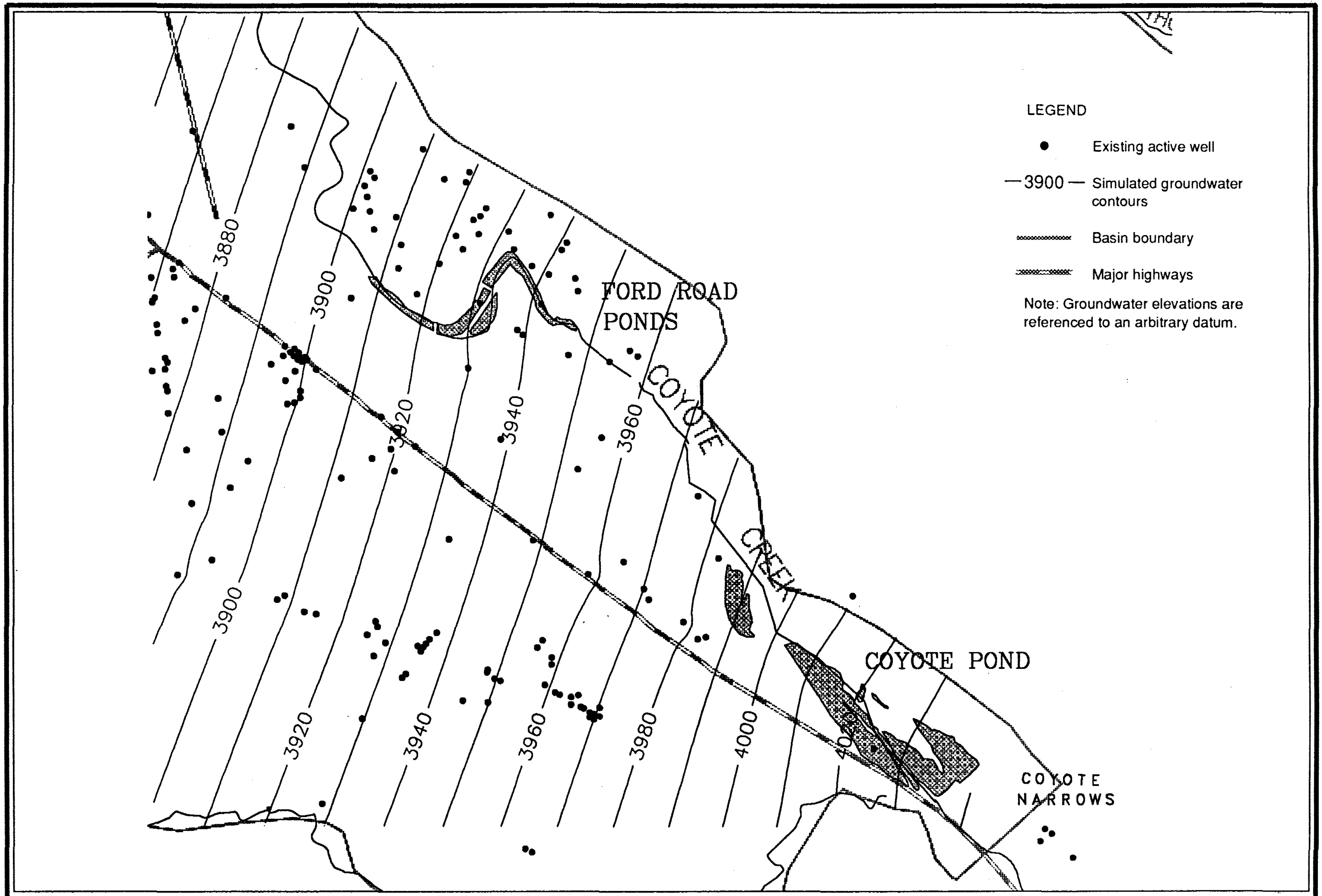
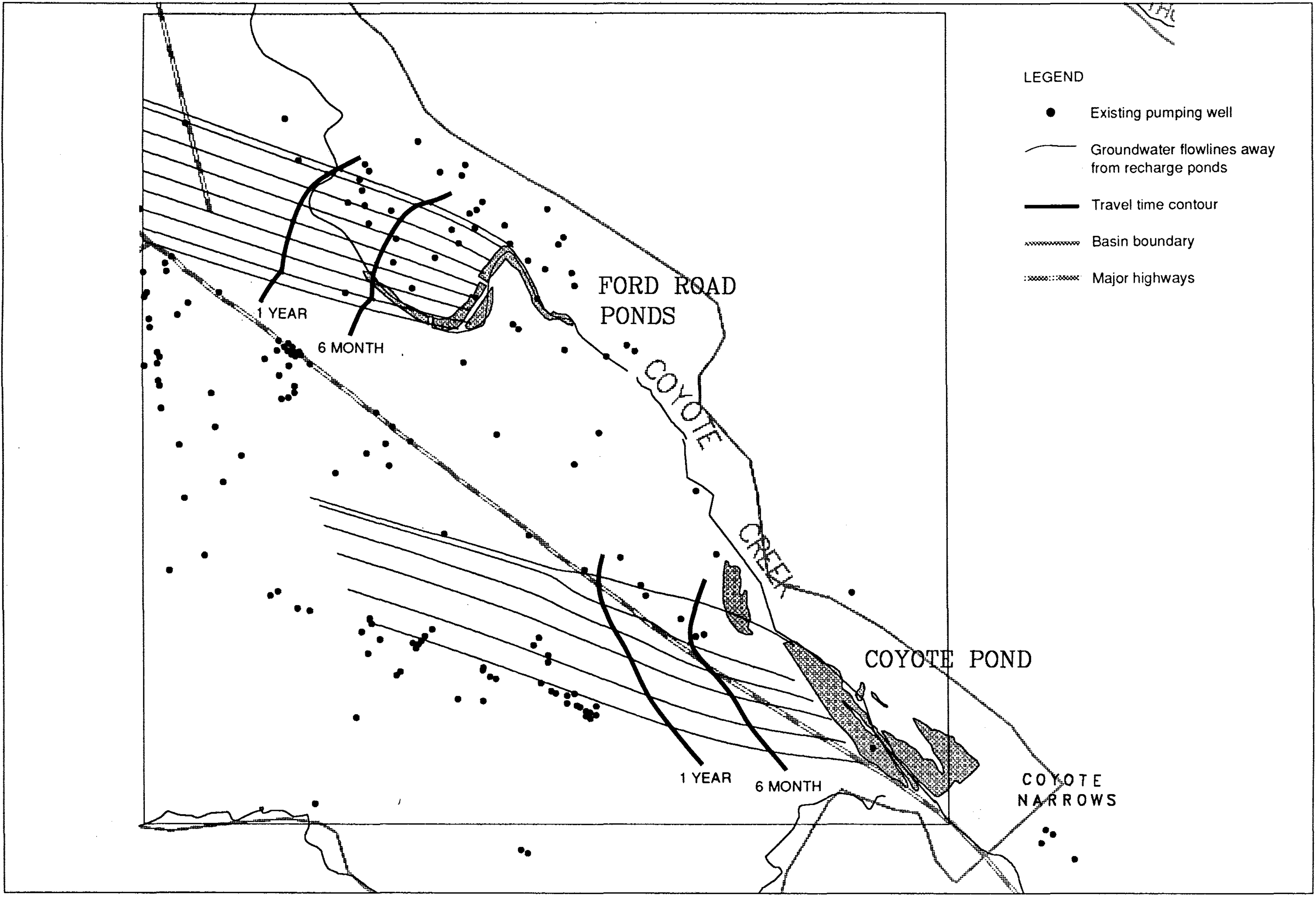
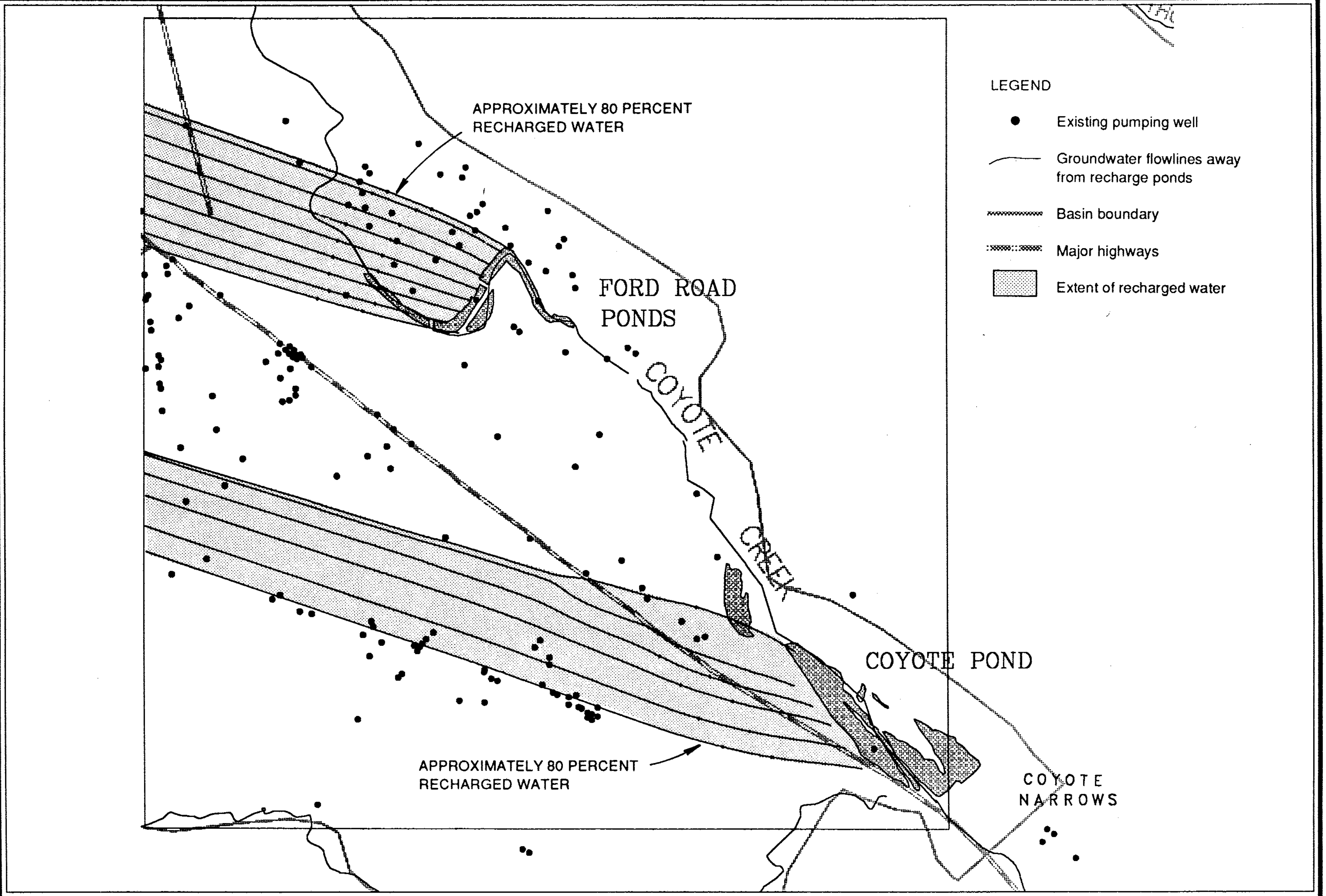


FIGURE 4-11
SPREADING BASIN LOCATIONS AND HYDRAULIC HEAD
DISTRIBUTION IN LAYER 2, SURFACE SPREADING ALTERNATIVE



0 1250 2500 5000
FEET

FIGURE 4-12
SPREADING BASIN LOCATIONS, GROUNDWATER FLOWLINES, AND TRAVEL TIME CONTOURS OF RECHARGED WATER IN LAYER 2, SURFACE SPREADING ALTERNATIVE



APPROXIMATELY 80 PERCENT RECHARGED WATER
FORD ROAD PONDS
COYOTE CREEK
COYOTE POND
APPROXIMATELY 80 PERCENT RECHARGED WATER
COYOTE NARROWS
LEGEND
● Existing pumping well
Groundwater flowlines away from recharge ponds
Basin boundary
Major highways
▨ Extent of recharged water
0 1250 2500 5000
FEET
N

FIGURE 4-13
RECHARGED WATER DISTRIBUTION IN LAYER 2,
SURFACE SPREADING ALTERNATIVE

LM4-13.AML SFO27295.LM

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approximately 80 percent recharged water. For these wells, the DHS maximum contribution requirement of 50 percent would not be met.

4.3.6 Assessment of Nearby Well Locations

SCVWD database records (SCVWD, 1992) suggest that 12 wells lie within 500 feet of the spreading basins. Therefore, the total number of wells that do not satisfy the horizontal distance and minimum retention time criteria is 21. The designations of these wells are shown in Table 4-1. Pumping information is available for 17 of these wells and suggests that these wells produced about 11 acre-feet per month in 1990.

It is likely that some of the reclaimed water placed in the spreading basins at the Coyote Creek Recharge Facility will flow downstream along Coyote Creek. Figure 4-14 gives a rough estimate of the number of wells that could be affected by the infiltration of this water. This information is presented only to suggest the number of wells that could be affected by this process. A much more detailed investigation of the interactions between Coyote Creek and the groundwater aquifer would be required before a more accurate analysis of the potential effects on wells could be obtained.

4.4 Limitations of Analysis

The use of an analytical solution for the simulation of the hydraulic head distribution requires the assumption of several conditions in the problem formulation. These are:

- Uniform transmissivity within model layers
- Uniform vertical hydraulic conductivity within model layers
- Infinite horizontal extent of the aquifers
- No storage of water in the aquitards
- Fluxes into and out of the aquifer system are at steady state

Several other assumptions made during the course of the analyses are:

- Insignificant effect of areal recharge on the hydraulic head of the upper aquifer zone

- Constant magnitude and direction of the regional hydraulic gradient

- Simulated boundary conditions are reasonable

The results presented in this memorandum are sensitive to the estimate of the aquifer hydraulic conductivity, and therefore transmissivity, used in the simulations. Sensitivity to other assumptions made throughout this analysis are probably less important. Because of the heterogeneous nature of the sediments in the Santa Clara Valley Groundwater Basin, aquifer hydraulic conductivity is uncertain and likely to vary at

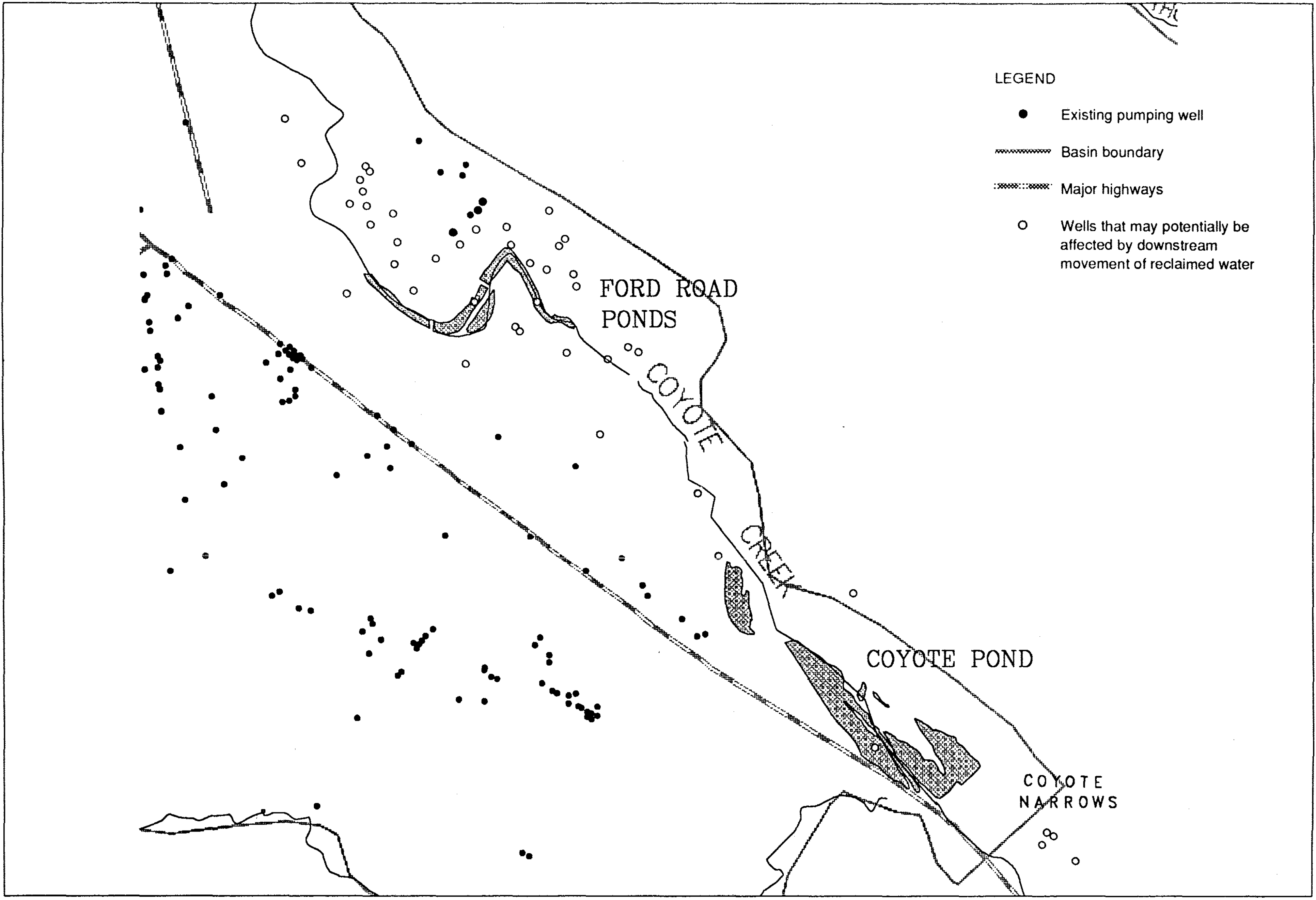

FIGURE 4-14
WELLS POTENTIALLY AFFECTED BY DOWNSTREAM FLOW
OF RECLAIMED WATER IN COYOTE CREEK

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July 29, 1992

each site. The relationship between recharge quantity and aquifer hydraulic conductivity is roughly linear. Therefore, if the assumed value of hydraulic conductivity used in the simulations is twice the actual values at the site, the quantity of water that can be injected will be only half of what is predicted by the simulations. The hydraulic conductivity values used in this analysis are believed representative for the sediments of this basin. However, natural variability in the geologic formations may result in deviations of up to 50 percent (plus or minus).

Section 5
Conclusions

Section 5
Conclusions

The results of this analysis suggest that it is feasible to recharge reclaimed water into the Santa Clara Valley Groundwater Basin. However, depending on the assumed configuration and location of the proposed facilities, DHS criteria may not be met. The major conclusions of this analysis are presented below and in Table 5-1.

5.1 Confined Zone Injection Alternative

- Approximately 3 mgd of water can be injected into the Confined Zone aquifer through 10 wells spaced from 1,200 to 1,500 feet
- Thirteen wells do not meet DHS minimum horizontal distance requirements for the assumed configuration and location
- Injected water will travel downgradient at about 350 feet per year
- Groundwater pumped from downgradient public water supply wells will be composed of nearly 100 percent injected water

5.2 Forebay Injection Alternative

- Approximately 25 mgd of water can be injected into the Forebay Area aquifer through 12 wells spaced at 2,000 feet
- Injected water will travel downgradient at approximately 1,300 feet per year
- Groundwater pumped from downgradient public water supply wells will be composed of approximately 75 percent injected water and 25 percent native groundwater
- One well lies within 2,000 feet of the assumed injection site

5.3 Coyote Creek Facility Alternative

- Approximately 18 mgd of water is now recharged using the Coyote Creek Recharge Facility.

- Percolated water will travel at approximately 2,400 feet per year in the vicinity of the Ford Road Ponds and 3,200 feet per year in the vicinity of Coyote Ponds

- A total of 21 wells are within 500 feet or 6 months' retention time of the Ford Road and Coyote Ponds

- Groundwater pumped from downgradient public water supply wells will consist of approximately 80 percent percolated water and 20 percent native groundwater

Table 5-1
Summary of Alternatives Analysis

Alternative	Recharge Quantity	Number of Injection Wells	Injection Well Spacing	Recharged Water Velocity	Percent Recharged Water Pumped from Downgradient Wells
Confined Zone Injection	2.8 mgd	10	1,200-1,500 ft	350 ft/yr	~100 %
Forebay Injection	25 mgd	12	2,000	1300 ft/yr	~ 75 %
	30 mgd	16	4,000	2,000 ft/yr	50 %
Coyote Facility	18 mgd	N/A	N/A	2400-3200 ft/yr	~ 80 %

Notes:

N/A = Category Not Applicable to Alternative

Section 6
Recommendations

Section 6

Recommendations

These recommendations are provided, in approximate order of priority, to provide insight into the additional information that may be required to prepare an Engineering Report for a DHS-approved recharge project. An Engineering Report is required by the DHS before they will approve and permit a recharge project.

6.1 Perform Evaluations of Guadalupe and Los Gatos Facilities

Additional analyses of the Guadalupe and Los Gatos Facilities should be performed, at the same level of detail as the Coyote Creek Recharge Facility analysis, to:

- Estimate the total potential surface recharge capacity using all three surface spreading facilities (Coyote, Guadalupe, and Los Gatos)

- Evaluate how well the other two facilities satisfy the proposed DHS criteria

6.2 Explore Alternative Methods of Reclaimed Water Recharge

A limited number of recharge alternatives were evaluated in this analysis. Additional alternatives that should be considered include:

- Deep injection into the deepest sediments of the basin
- Recharge through injection wells located in other areas of the Forebay

6.3 Conduct Aquifer Testing on Existing Wells

The greatest uncertainty in the results presented here lies in the assumed value of the aquifer hydraulic conductivity and transmissivity. Site-specific hydraulic testing will help improve estimates of transmissivity and storativity at potential recharge locations.

6.4 Construct Monitoring Wells at Potential Recharge Site Locations

If adequate monitoring wells do not currently exist at proposed recharge sites, additional monitoring wells should be constructed to:

- Obtain site-specific water level measurements including depth to groundwater beneath surface spreading basins
- Provide additional estimates of site-specific aquifer properties (transmissivity, storativity, etc)
- Collect soil samples for laboratory testing to improve estimates of transport porosity and, therefore, reclaimed water velocity and retention time in the aquifer

A pilot scale injection well could also be constructed to test the response of the aquifer to injection of reclaimed water.

6.5 Numerical Simulations of Potential Recharge Sites

Because of the limitations of analytical hydraulic head solution routines, numerical simulations may be required to obtain greater confidence in estimates of recharge quantities and maximum reclaimed water contribution to public water supply wells. Using numerical simulations the following improvements could be achieved:

- Local numerical models (possibly enlargements of the basinwide model) with much denser grid spacing, and, therefore, much greater resolution, in the areas where recharge would be conducted
- Use of simulated flows and water levels from the basinwide model to better define boundary conditions for the local models
- Use of a particle tracking/solute transport post-processor (such as MT3D) to improve the accuracy of the reclaimed water flow path simulations and maximum reclaimed water contribution estimates
- Investigation of the effects of transient conditions on various recharge scenarios

6.6 Study Potential Reclaimed Water/Aquifer Material Interactions

The concern has been expressed that constituents in reclaimed water could interact with basin sediments and/or aquifer sediments to significantly reduce aquifer permeability and percolation pond performance. These processes should be investigated in more detail, using project-specific water quality and site-specific soils data, to assess whether these processes may affect project performance.

Section 7
References

Section 7
References

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Appendix B
Basinwide Model Simulations

Appendix B

Basinwide Model Simulations

Using the Basinwide Model, two simulations were performed to begin evaluating the effect of injecting reclaimed water in the forebay. Predicting the actual effect of injecting reclaimed water into the forebay can not be accomplished by only these two simulations; these simulations provide only a general picture of the potential effects that may be expected. The two simulations are based on scenarios developed by the SCVWD staff, and agreed to by City staff. The purpose of the two scenarios is to suggest potential effects of injection during a number of consecutive "average" and "wet" years. The following paragraphs present technical details of the model input and output for the two simulations. A complete description of the basinwide groundwater model is included in the Basinwide Groundwater Model Technical Memorandum, scheduled for publication in September 1992.

Simulation Number One

Input

The input for simulation number one is summarized in Table B-1. A description of each the input parameters are presented in the following paragraphs.

Initial head conditions for simulation number one are the third quarter, 1971 head distribution from the groundwater model calibration. The SCVWD staff selected these initial conditions because they calculate that there is a 48 percent exceedence probability for this hydraulic head distribution (i.e., it is, in some sense, an "average" water level condition.)

Recharge from rainfall in simulation number one is calculated from rainfall measurements at two stations: Station 86 in San Jose and Station 49 in Los Gatos. Annual rainfall of 14.1 inches, the average annual rainfall in San Jose, was assigned to Station 86. The rainfall was divided into quarterly rainfall based on historical quarterly rainfall percentages. The historical average first quarter percentage was multiplied by 14.1 inches, and that result was used as the first quarter rainfall for all years in simulation one. A similar procedure was used to determine quarterly rainfall at Station 86 for all four quarters. Rainfall at Station 49 is set at the 1973 distribution for all years in simulation number one.

Water deliveries to the basin consist of water from Hetch-Hetchy, the South Bay Aqueduct, nonagricultural groundwater deliveries, nonagricultural surface water diversions, agricultural groundwater deliveries, and miscellaneous diversions by the San Jose Water Company. Values for most of the components are set at historical averages. Exceptions include Hetch-Hetchy and South Bay Aqueduct deliveries, which are set at the maximum contracted quantities. Agricultural groundwater pumping is set at the average of only the most recent years, reflecting the recent decline in agricultural water use.

The quantity of facility recharge is set at the historical maximum of 124,000 acre-feet per year. To meet DOHS criteria, approximately 22,000 acre-feet are diverted each year from the ponds for blending with reclaimed water before injection. Therefore, just over 100,000 acre-feet per year of water recharge the SCVWD ponds.

Forty mgd of combined reclaimed and raw water are injected into the forebay through 20 injection wells distributed in two well fields. One well field corresponds to the well field discussed in Chapter 3; approximately 25 mgd are injected in these 12 wells between Guadalupe River and Los Gatos Creek. The second well field injects 15 mgd into the Santa Teresa Basin. The Santa Teresa well field was developed by spacing eight wells throughout the subbasin without concern for whether or not they meet the proposed DOHS guidelines for injection of reclaimed water. The model cells in which the injection wells are located are listed in Table B-1 and are displayed on Figure B-2. The injection rate is the same for each of the 20 wells (approximately 1,120 acre-feet/year). Injection is distributed equally among all active model layers at the given row and column; if three layers are active, the well's injection rate is split into thirds and equal injection rates are applied to each layer.

Annual pumping in simulation number one is set at 150,000 acre-feet per year; this is an average amount of pumping for the basin. The areal and temporal pumping distribution mimics the 1989 pumping distribution.

Results

The purpose of the first simulation is to examine potential effects of injection under average climatic conditions. Because the facility recharge is set at the maximum historical recharge rate, and the rainfall rate applied at the Los Gatos station is moderately high, the first simulation is slightly biased towards wetter climatic conditions, when the basin would store more water.

Results of the simulation are presented in the hydrographs labeled "Potable 1," which are included in this appendix. The selected hydrographs were chosen to provide a quick review of the results and were selected from wells that calibrated well. Locations of the hydrographed wells are shown on Figure B-1.

Plotted with the simulated hydrographs are water level elevations that were designated as the maximum desirable water level for each hydrograph. The maximum water level elevation is arbitrarily defined as the higher of the highest water level measured in the last 15 years, or 25 feet below ground surface.

Inferences that can be made from the hydrographs include:

- The 5 hydrographs in the Santa Teresa Basin (wells in Township 8-South) generally rise above the maximum water level elevation. This appears to be a result of the fact the initial water levels are near the maximum water level elevation, allowing little room to accept injected water.
- Water levels in wells immediately downgradient of the 25-mgd injection well field (Wells 07S1E31A01 and 07S1W25L01) rise to the maximum water level.

Eight hydrographs (Wells 06S2W33A02, 07S1E06L01, 07S1E07F01, 07S1E07R99, 07S1W02G01, 07S1W09E02, 07S1W22E02, and 07S1W21A01) display simulated pressures from confined zones and not true water table elevations. These hydrographs are included to complete areal distribution of the data, but high pressures and high fluctuations in these hydrographs do not indicate high water table conditions.

Simulation Number Two

Input

Input for simulation number two is summarized in Table B-3, and descriptions of each input parameter are presented in the following paragraphs.

The second simulation begins with three years of near average hydrologic conditions, then switches to five years of above average recharge conditions, while maintaining average pumping and water deliveries. Initial conditions are identical to those used in the first simulation.

Rainfall, water deliveries, and pumping conditions for the first three years of the simulation are identical to the first simulation. Rainfall at San Jose during the last five years of the simulation is set at 17.4 inches. This is a rainfall that has a 10 percent exceedence probability based on historical data from San Jose. Simulated rainfall at Los Gatos remains at 1973 levels throughout the second simulation. Pumping rates, delivered water quantities, and sewage flows during the last five years of the simulation are the same as for the first three years (average conditions).

Facility recharge during the first three years of simulation is set at 102,000 acre-feet per year. As with the first simulation, 22,000 acre-feet of this water are diverted to blend with the reclaimed water before injection, resulting in 80,000 acre-feet of water being spread in the recharge ponds. Facility recharge during the last five years of the second simulation is increased to 122,000 acre-feet per year, which is near the historical maximum recharge rate. Again, 22,000 acre-feet of this water are diverted to the injection wells, resulting in an effective recharge rate of 100,000 acre-feet/year.

Forty mgd of combined reclaimed and raw water are injected through 20 injection wells, distributed in two well fields. As with the first simulation, one well field corresponds to the well field discussed in the Chapter 3; approximately 25 mgd are injected in these 12 wells between Guadalupe River and Los Gatos Creek. The second well field injects 15 mgd along the west side of the basin, north of Los Gatos Creek. This area was chosen because the apparently deeper groundwater table in this area appears to provide a larger storage capacity. Again, this well field was placed without analysis of whether or not it met the proposed DOHS guidelines for injection of reclaimed water. The model cells in which the injection wells are located in are listed in Table B-1 and are displayed on Figure B-1.

Results

Results of the second simulation are presented in the hydrographs labeled "Potable 2," included in this appendix. Results are compared with the same groundwater level elevation defined for the first simulation.

Inferences that can be made from the hydrographs include:

- Hydrographs from the two wells nearest the 15-mgd injection well field (Wells 07S1W28RO1 and 07S1W30C01) do not reach the maximum water level elevation during the simulation period.
- Wells in the Santa Teresa Basin (wells in Township 8-South) do exceed the maximum water level elevations. No injection takes place in the Santa Teresa Basin, and the water levels in the Santa Teresa Basin begin to rise only during the last five years of simulation. Therefore, it appears as though the water level rise in the Santa Teresa Basin is due to wet hydrologic conditions and not injection.
- As might be expected, the generally upward hydrograph trend is steeper during the last five years than during the first three years. The change in trend, however, is slight for most parts of the basin.

Table B-2 Model Cells with Injection Wells

First Simulation			Second Simulation		
	Row	**Column**		**Row**	**Column**
Well field number one. (Between Los Gatos and Guadalupe Creeks)	50	58	Well field number one. (Between Los Gatos and Guadalupe Creeks)	50	58
	50	60		50	60
	50	62		50	62
	50	64		50	64
	49	58		49	58
	49	60		49	60
	49	62		49	62
	49	64		49	64
	48	58		48	58
	48	60		48	60
	48	62		48	62
	48	64		48	64
Well field number two. (Santa Teresa basin)	45	76	Well field number two. (North and west of Los Gatos Creek)	49	36
	45	79		49	38
	45	82		49	41
	43	77		49	43
	43	80		51	36
	43	83		51	38
	40	78		51	41
	40	81		51	43

Table B-1
Summary of Simulation Number One Input

Initial Conditions:	Third quarter 1971 conditions, derived from the model calibration.
Rainfall:	14.1 inches at San Jose (average conditions), and 37.24 inches at Los Gatos (based on 1973 data)
Water Deliveries:	Hetch Hetchy = 76,000 acre-feet/year (contracted maximum) South Bay Aqueduct = 126,000 acre-feet/year (contracted maximum) Nonagricultural surface water deliveries = 1000 acre-feet/year Nonagricultural groundwater deliveries = 144,000 acre-feet/year (average) San Jose Water Company diversions = 10,000 acre-feet/year Agricultural groundwater pumping = 6,000 acre-feet/year Flows at the sewage plant the same as 1988.
Facility Recharge:	102,000 acre-feet/year. (124,000 acre-feet/year minus 22,000 acre-feet which is diverted each year for mixing with reclaimed water before injection.)
Injection:	40 mgd in two well fields: one between Los Gatos and Guadalupe Creeks, and one in the Santa Teresa Basin.
Pumping:	150,000 acre-feet/year (average)

Table B-3
Summary of Simulation Number Two Input

Initial Conditions:	Third quarter 1971 conditions, derived from the model calibration.	
Rainfall:	First 3 Years: 14.1 inches at San Jose (average conditions), and 37.24 inches at Los Gatos (wet conditions, based on 1973 data)	Second 5 Years: 17.4 inches at San Jose (wet conditions), and 37.24 inches at Los Gatos (wet conditions, based on 1973 data)
Water Deliveries:	Hetch Hetchy = 76,000 acre-feet/year (contracted maximum) South Bay Aqueduct = 126,000 acre-feet/year (contracted maximum) Nonagricultural surface water deliveries = 1000 acre-feet/year Nonagricultural groundwater deliveries = 144,000 acre-feet/year (average) San Jose Water Company diversions = 10,000 acre-feet/year Agricultural groundwater pumping = 6,000 acre-feet/year Flows at the sewage plant the same as 1988.	
Facility Recharge:	First 3 Years: 80,000 acre-feet/year. (102,000 acre-feet/year of which 22,000 acre-feet is diverted each year for mixing with reclaimed water before injection.)	Second 5 Years: 100,000 acre-feet/year. (122,000 acre-feet/year of which 22,000 acre-feet is diverted each year for mixing with reclaimed water before injection.)
Injection:	40 mgd in two well fields: one between Los Gatos and Guadalupe Creeks, and one north of Los Gatos Creek.	
Pumping:	150,000 acre-feet/year (average)	

Table B-1
Summary of Simulation Number One Input

Initial Conditions:	Third quarter 1971 conditions, derived from the model calibration.
Rainfall:	14.1 inches at San Jose (average conditions), and 37.24 inches at Los Gatos (based on 1973 data)
Water Deliveries:	Hetch Hetchy = 76,000 acre-feet/year (contracted maximum) South Bay Aqueduct = 126,000 acre-feet/year (contracted maximum) Non-agricultural surface water deliveries = 1000 acre-feet/year Non-agricultural groundwater deliveries = 144,000 acre-feet/year (average) San Jose Water Company diversions = 10,000 acre-feet/year Agricultural groundwater pumping = 6,000 acre-feet/year Flows at the sewage plant the same as 1988.
Facility Recharge:	102,000 acre-feet/year. (124,000 acre-feet/year minus 22,000 acre-feet which is diverted each year for mixing with reclaimed water prior to injection.)
Injection:	40 mgd in two well fields: one between Los Gatos and Guadalupe Creeks, and one in the Santa Teresa Basin.
Pumping:	150,000 acre-feet/year (average)

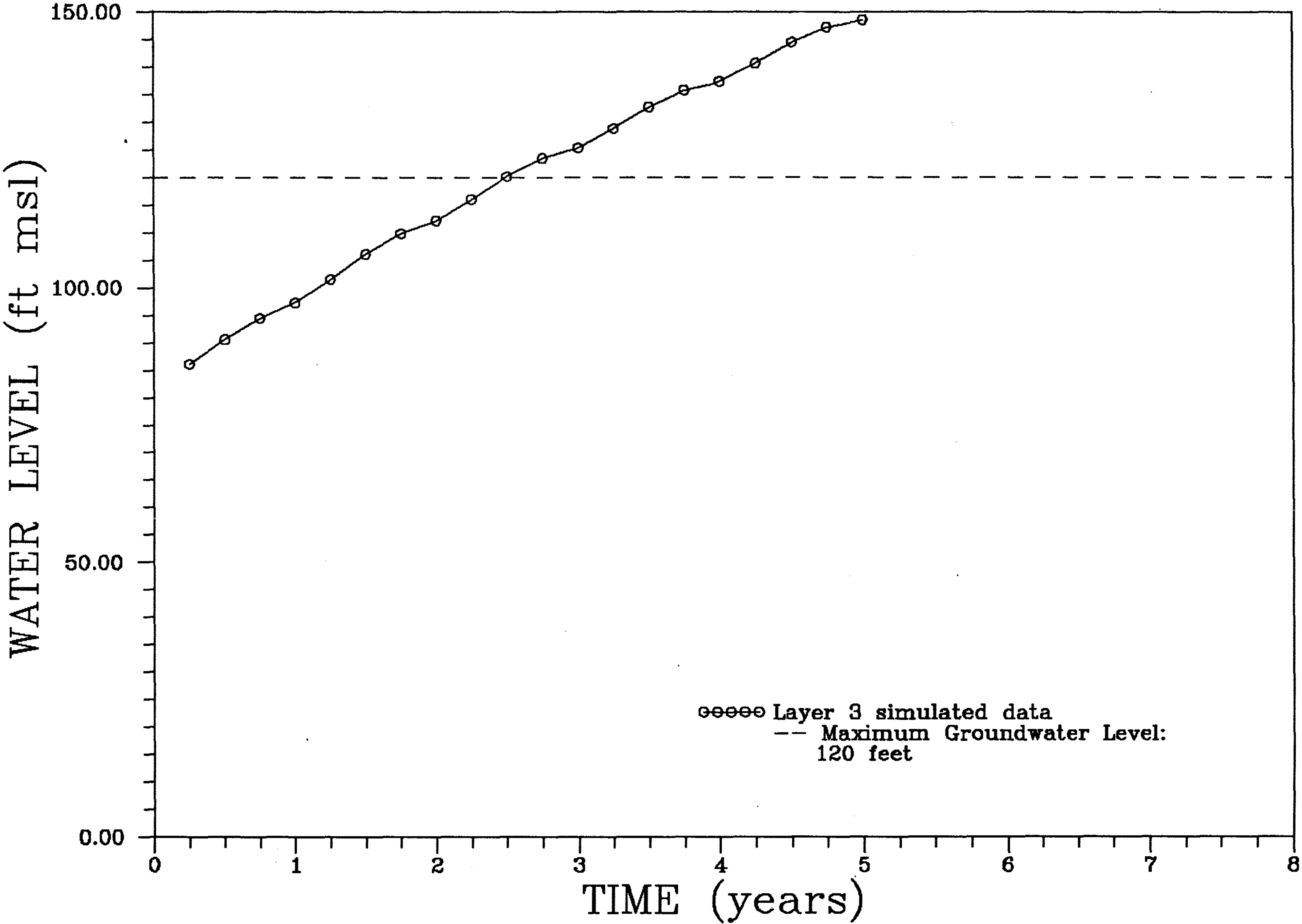
Table B-2 Model Cells with Injection Wells

First Simulation			Second Simulation		
Well field	Row	Column	Well field	Row	Column
number one. (Between Los Gatos and Guadalupe Creeks)	50	58	number one. (Between Los Gatos and Guadalupe Creeks)	50	58
	50	60		50	60
	50	62		50	62
	50	64		50	64
	49	58		49	58
	49	60		49	60
	49	62		49	62
	49	64		49	64
	48	58		48	58
	48	60		48	60
	48	62		48	62
	48	64		48	64
Well field number two. (Santa Teresa basin)	45	76	Well field number two. (North and west of Los Gatos Creek)	49	36
	45	79		49	38
	45	82		49	41
	43	77		49	43
	43	80		51	36
	43	83		51	38
	40	78		51	41
	40	81		51	43

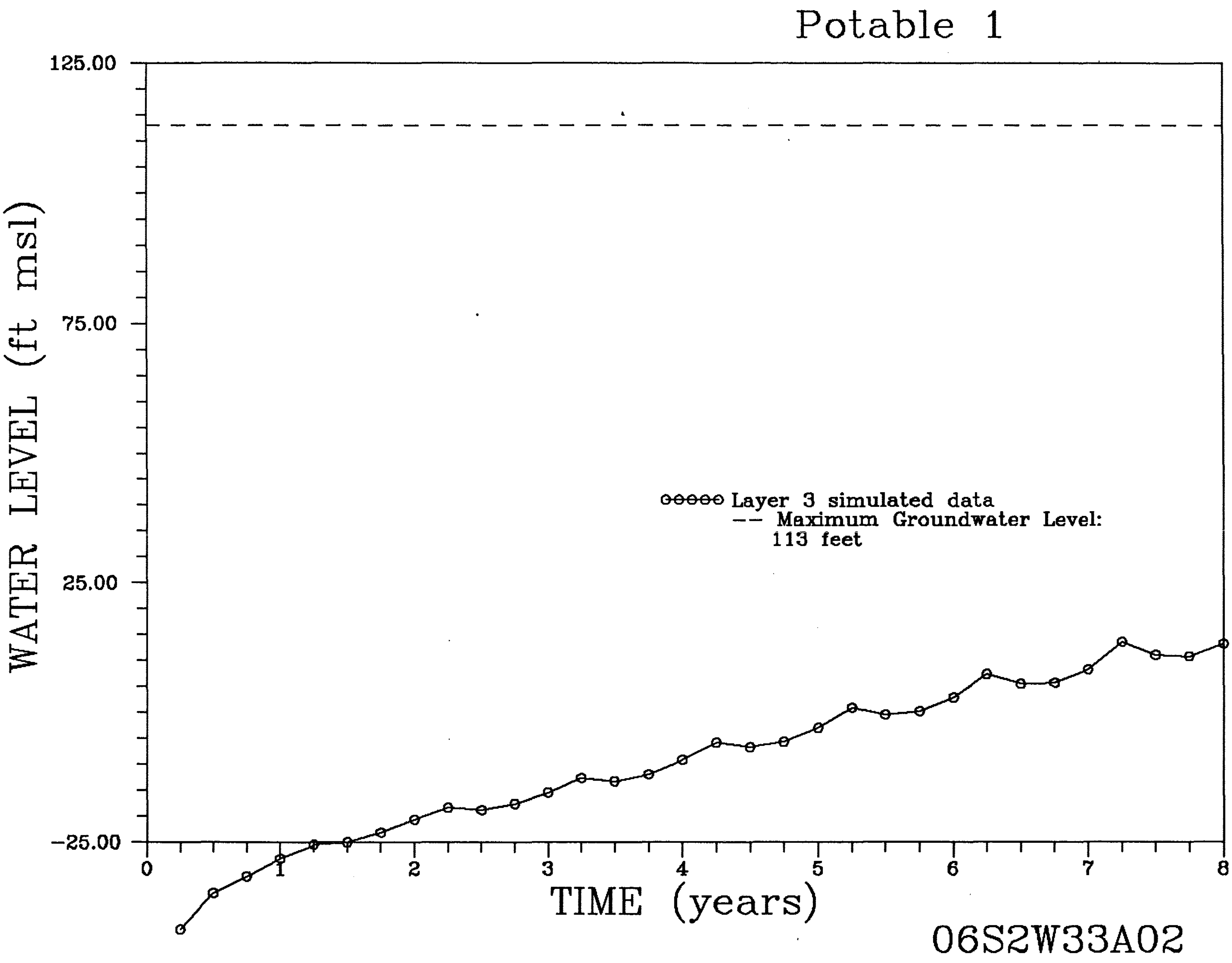
Table B-3
Summary of Simulation Number Two Input

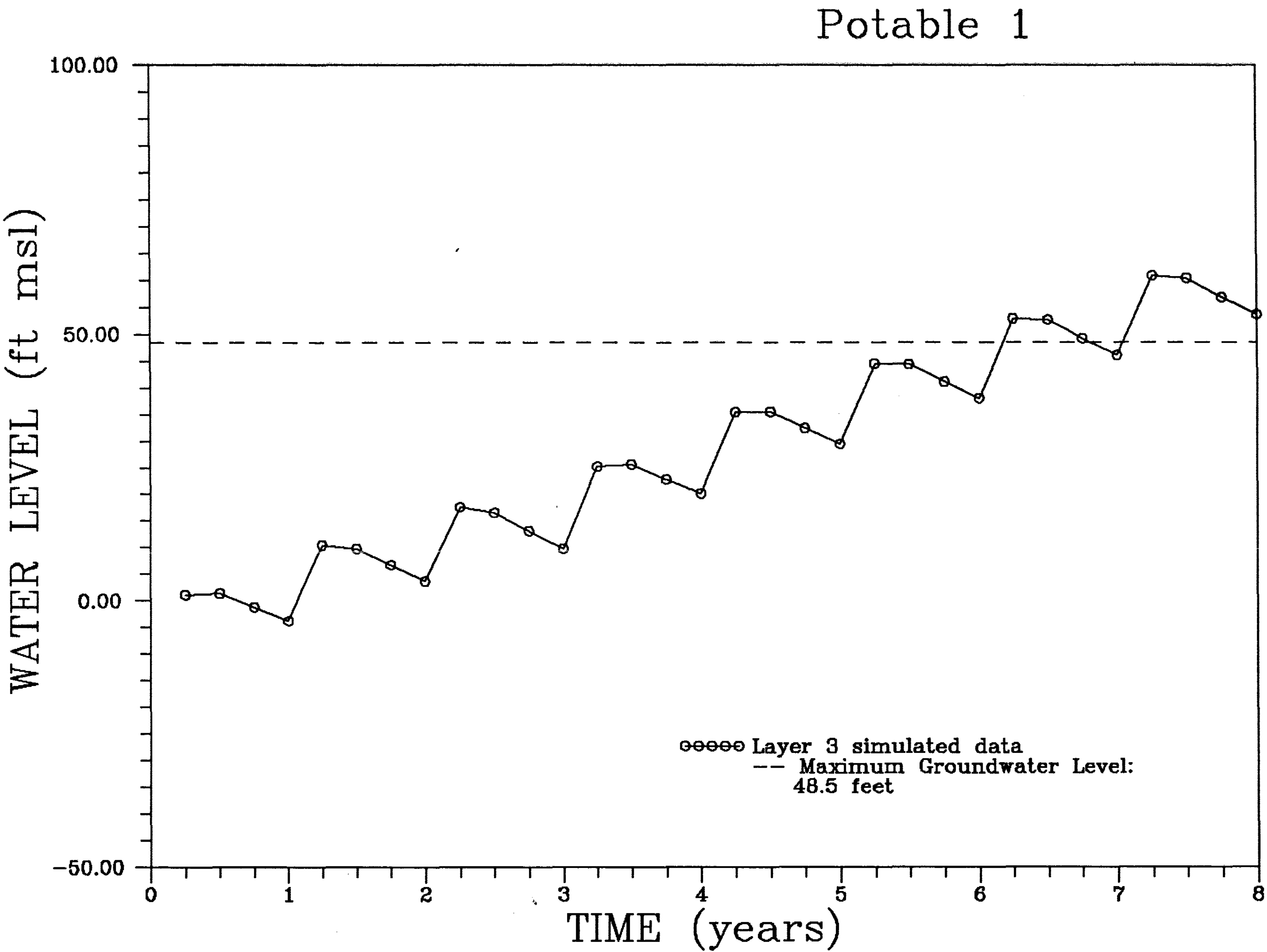
Initial Conditions:	Third quarter 1971 conditions, derived from the model calibration.	
Rainfall:	First 3 Years: 14.1 inches at San Jose (average conditions), and 37.24 inches at Los Gatos (wet conditions, based on 1973 data)	Second 5 Years: 17.4 inches at San Jose (wet conditions), and 37.24 inches at Los Gatos (wet conditions, based on 1973 data)
Water Deliveries:	Hetch Hetchy = 76,000 acre-feet/year (contracted maximum) South Bay Aqueduct = 126,000 acre-feet/year (contracted maximum) Non-agricultural surface water deliveries = 1000 acre-feet/year Non-agricultural groundwater deliveries = 144,000 acre-feet/year (average) San Jose Water Company diversions = 10,000 acre-feet/year Agricultural groundwater pumping = 6,000 acre-feet/year Flows at the sewage plant the same as 1988.	
Facility Recharge:	First 3 Years: 80,000 acre-feet/year. (102,000 acre-feet/year of which 22,000 acre-feet is diverted each year for mixing with reclaimed water prior to injection.)	Second 5 Years: 100,000 acre-feet/year. (122,000 acre-feet/year of which 22,000 acre-feet is diverted each year for mixing with reclaimed water prior to injection.)
Injection:	40 mgd in two well fields: one between Los Gatos and Guadalupe Creeks, and one north of Los Gatos Creek.	
Pumping:	150,000 acre-feet/year (average)	

Potable 1

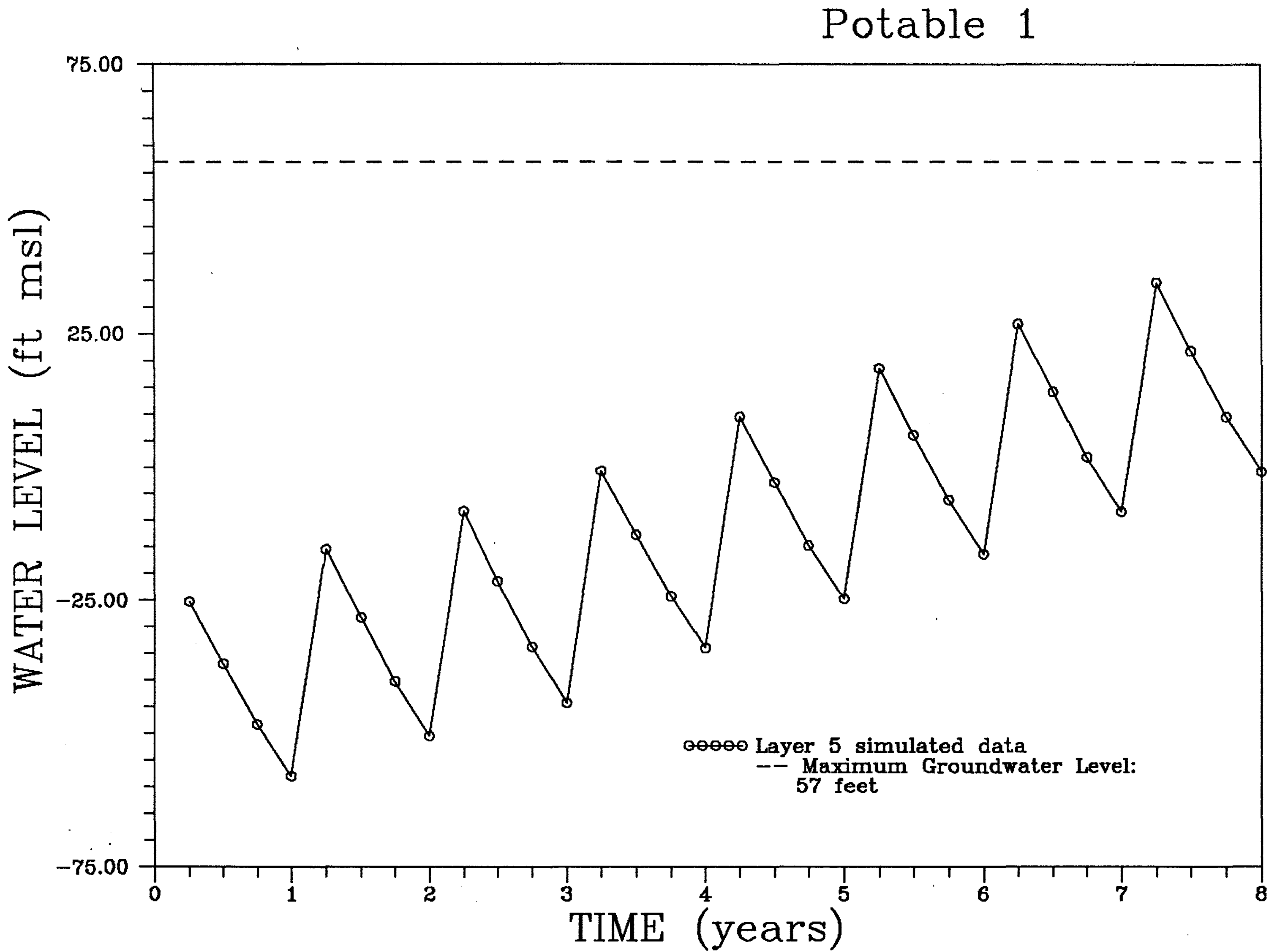


07S1E31A01

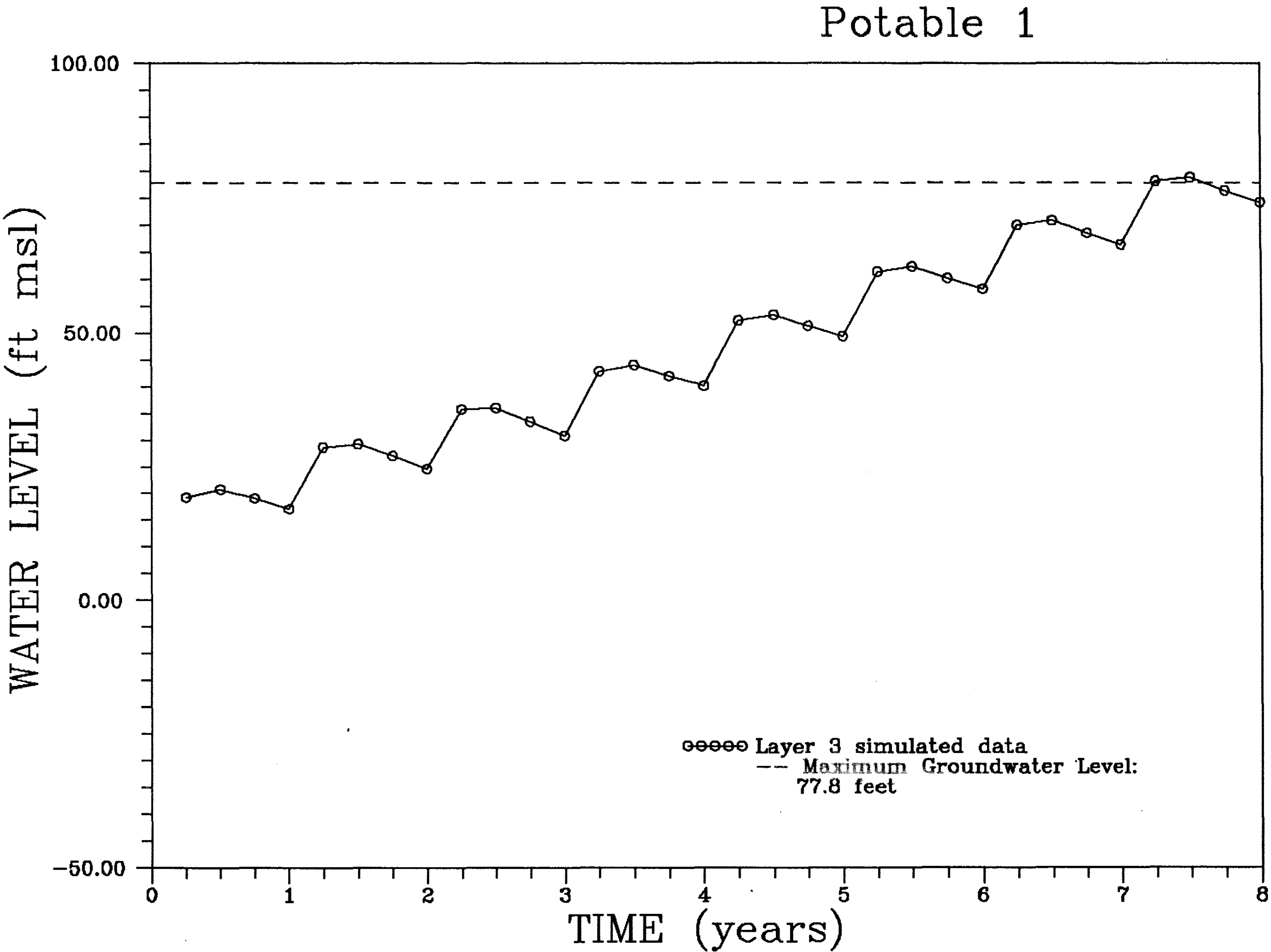

Potable 1
125.00
75.00
25.00
-25.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (years)
Layer 3 simulated data
-- Maximum Groundwater Level:
113 feet
06S2W33A02


Potable 1
100.00
50.00
0.00
-50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (years)
Layer 3 simulated data
Maximum Groundwater Level:
48.5 feet

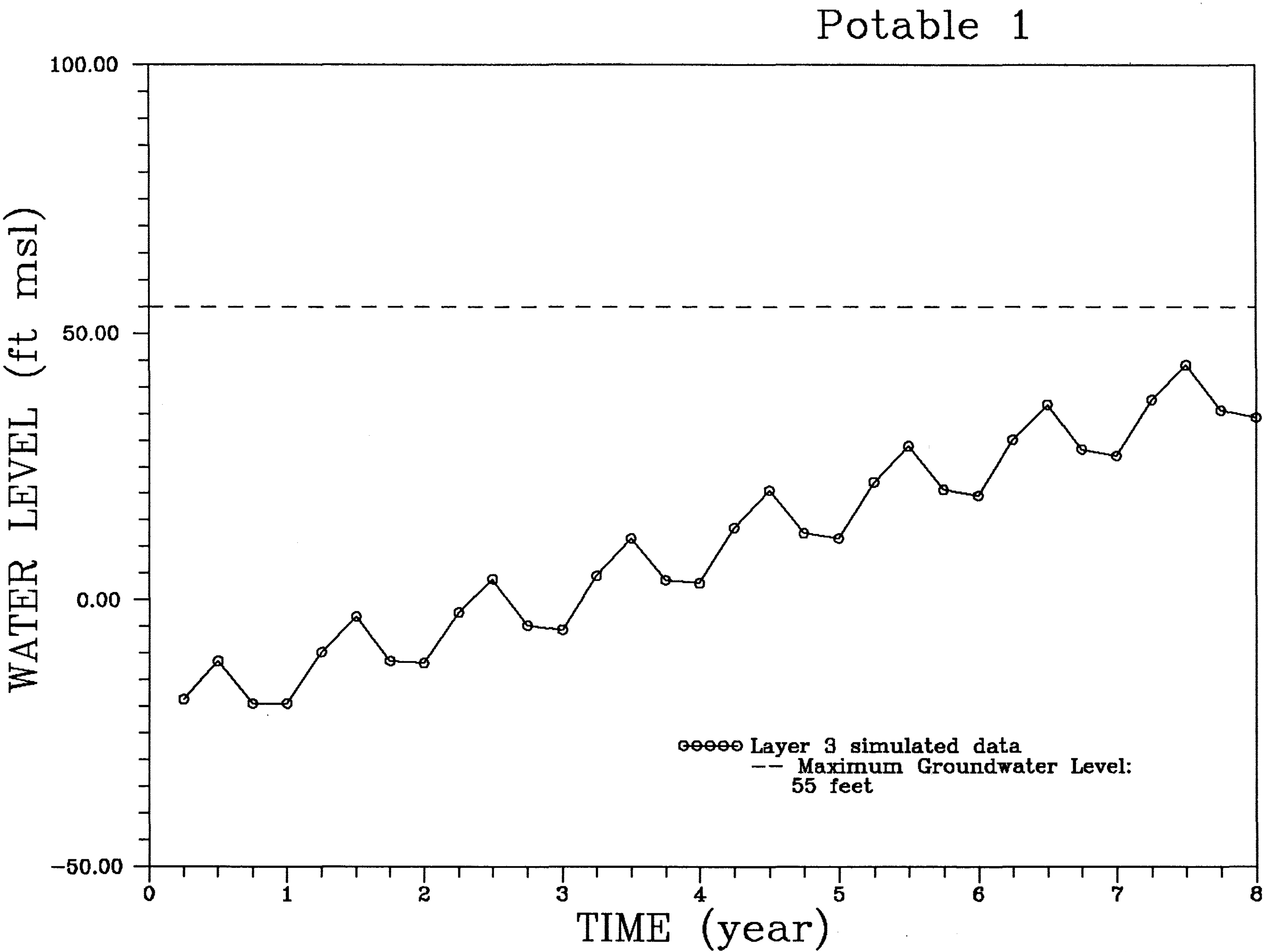
07S1E06L01


Potable 1
75.00
25.00
-25.00
-75.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (years)
ooooo Layer 5 simulated data
-- Maximum Groundwater Level:
57 feet

07S1E07F01

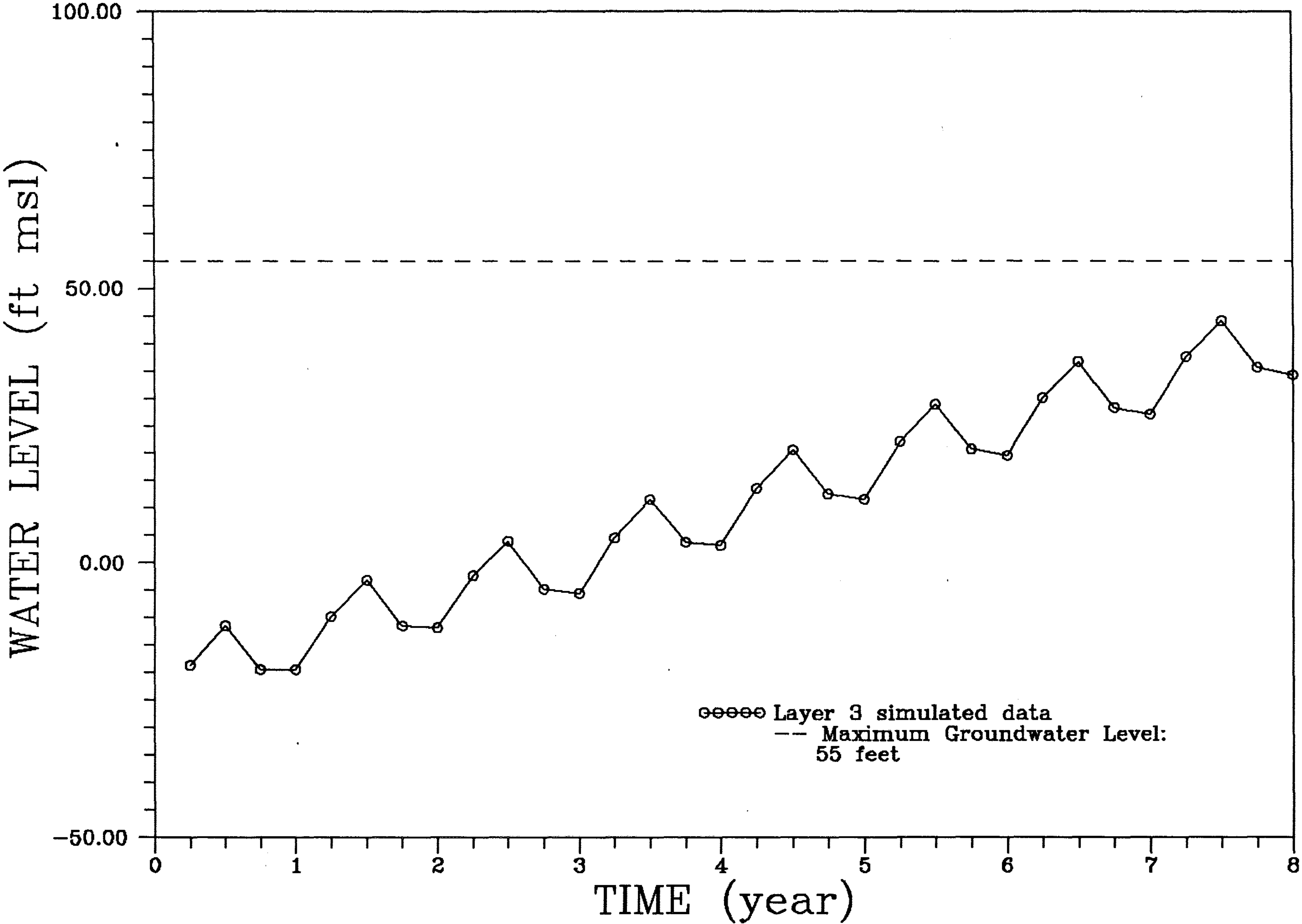

Potable 1
100.00
50.00
0.00
−50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (years)
ooooo Layer 3 simulated data
-- Maximum Groundwater Level:
77.8 feet

07S1E07R99


Potable 1
100.00
50.00
0.00
-50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
ooooo Layer 3 simulated data
-- Maximum Groundwater Level:
55 feet

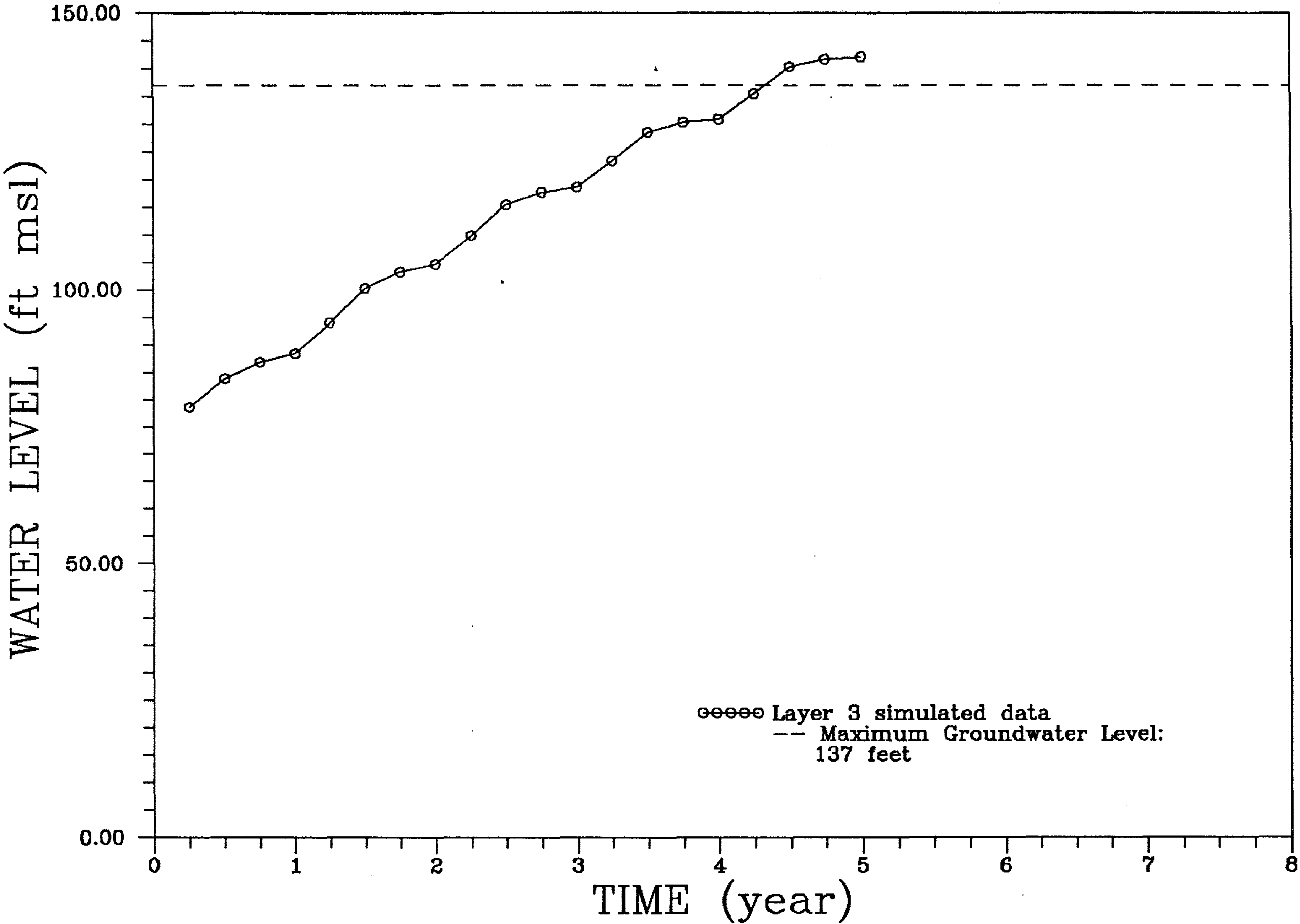
07S1W09E02

Potable 1

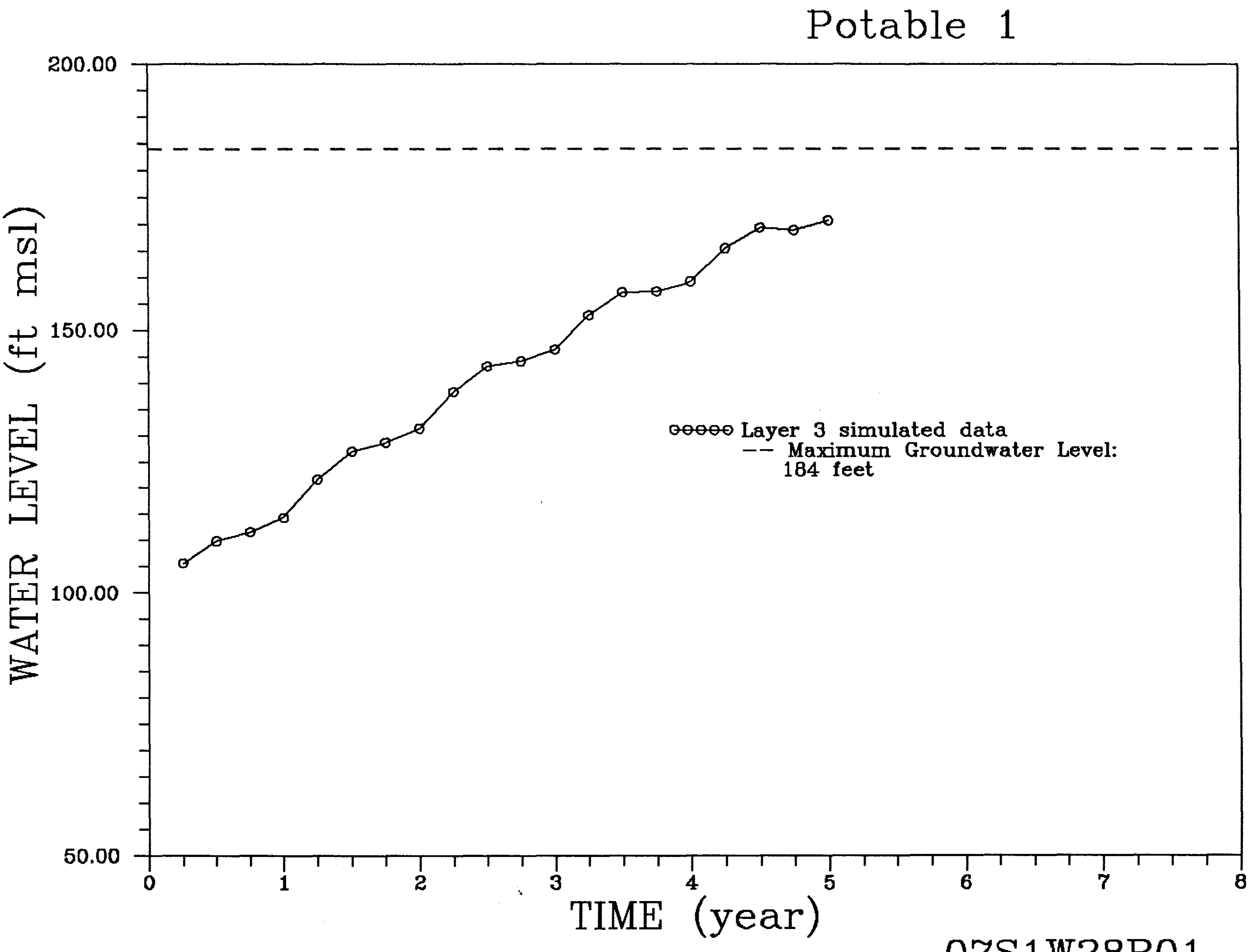


07S1W09E02

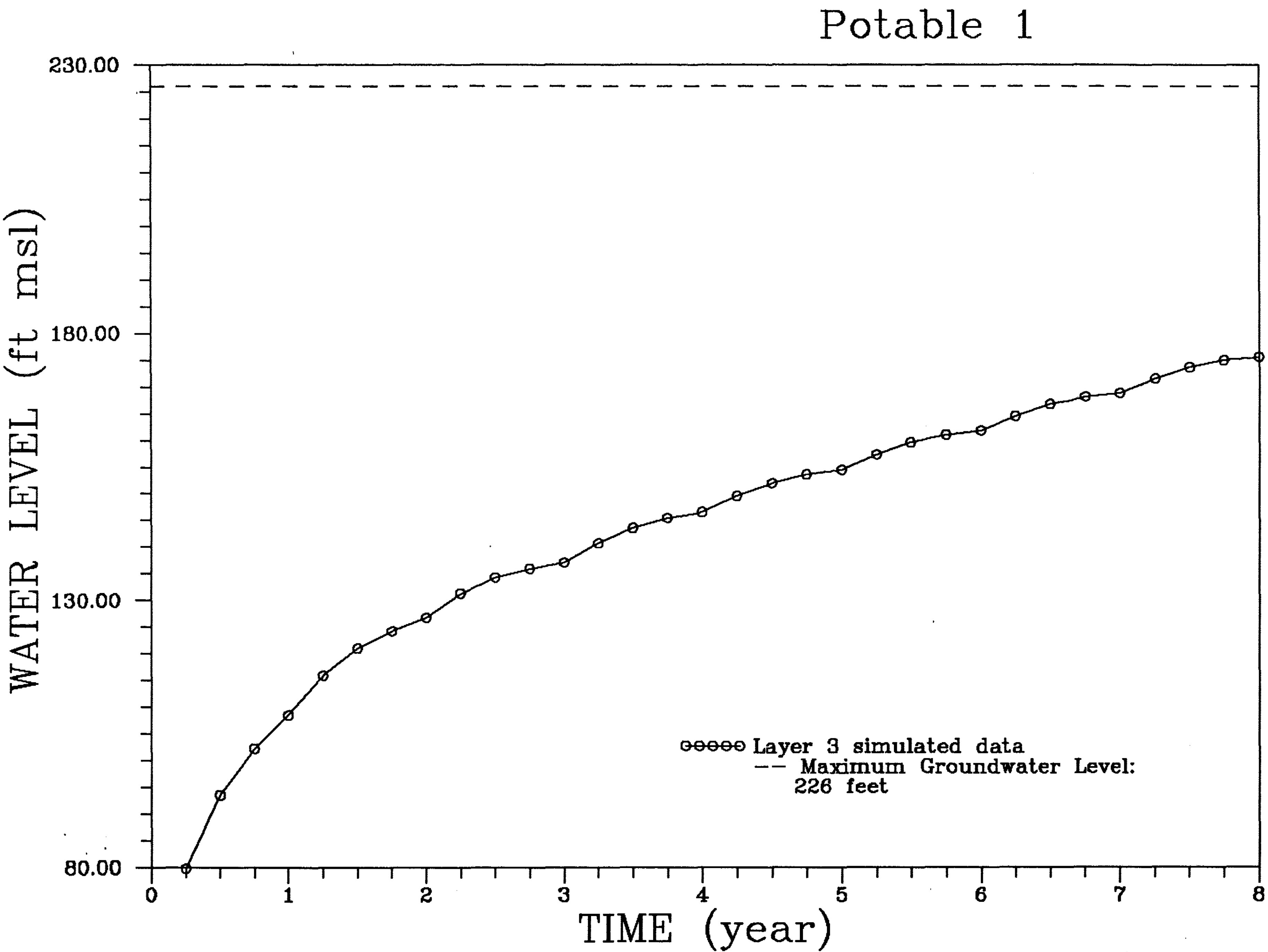
Potable 1



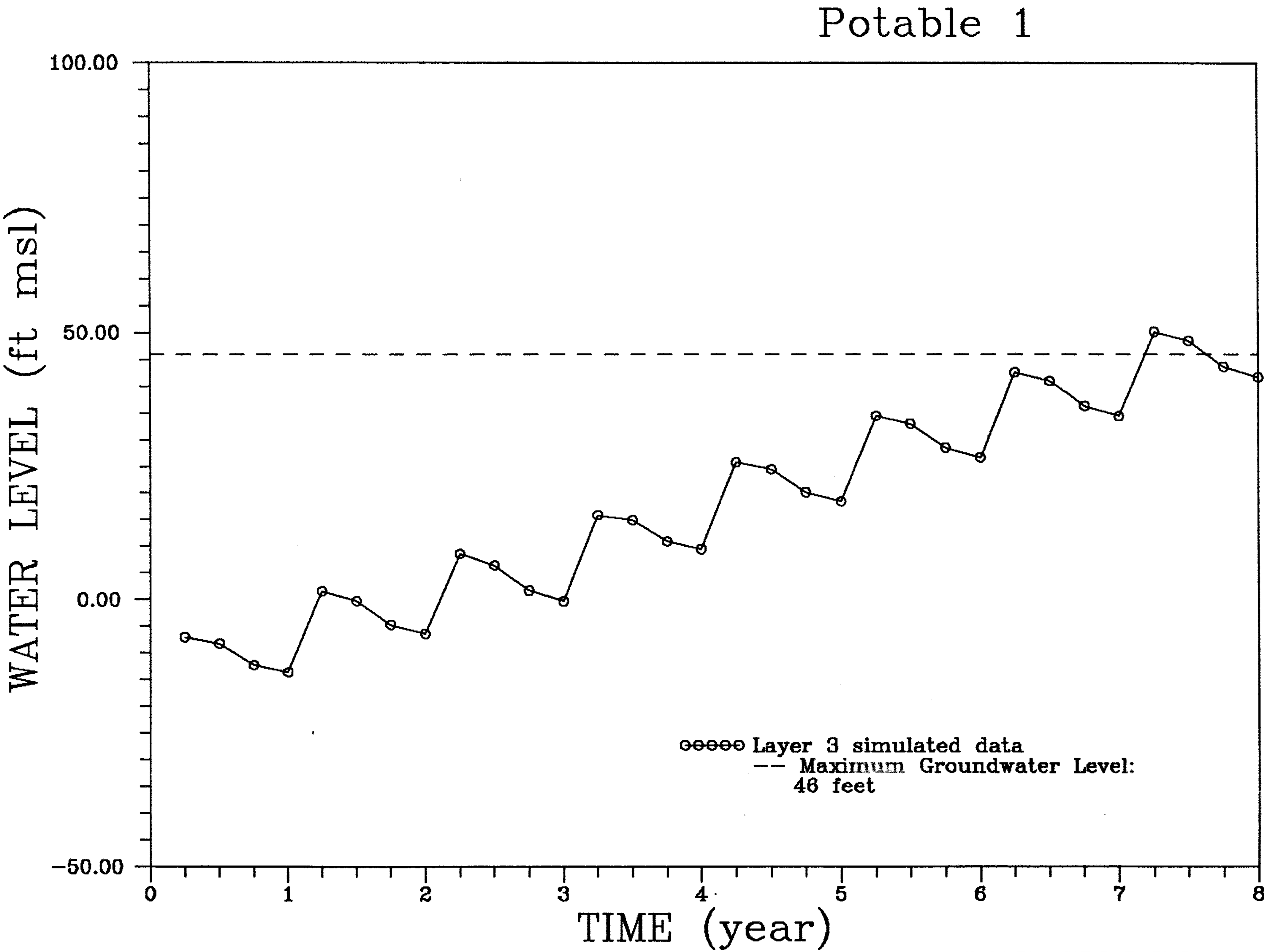
07S1W25L01


Potable 1
200.00
150.00
100.00
50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
Layer 3 simulated data
-- Maximum Groundwater Level: 184 feet

07S1W28R01

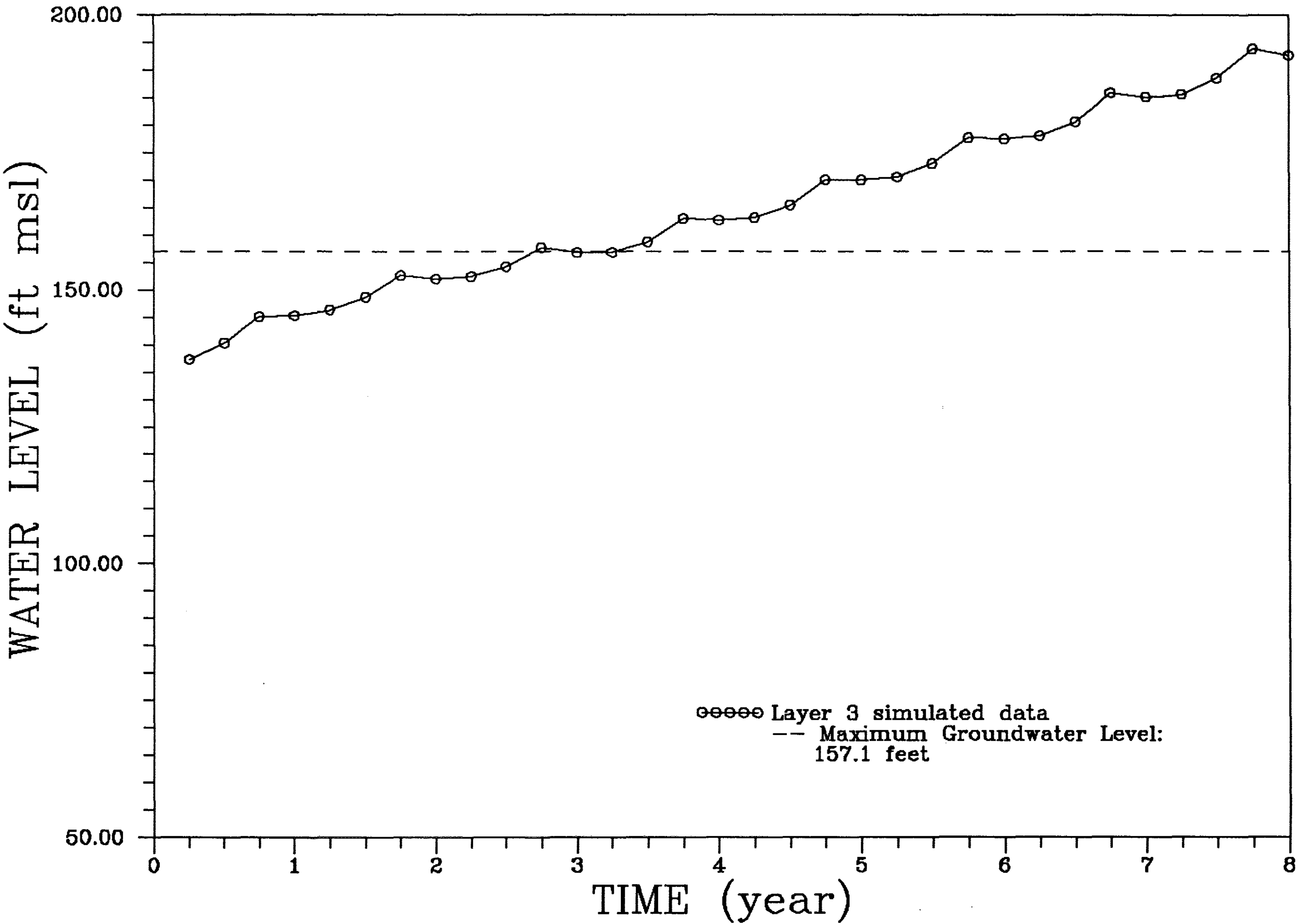

Potable 1
WATER LEVEL (ft msl)
230.00
180.00
130.00
80.00
TIME (year)
0
1
2
3
4
5
6
7
8
Layer 3 simulated data
Maximum Groundwater Level: 226 feet

07S1W30C01

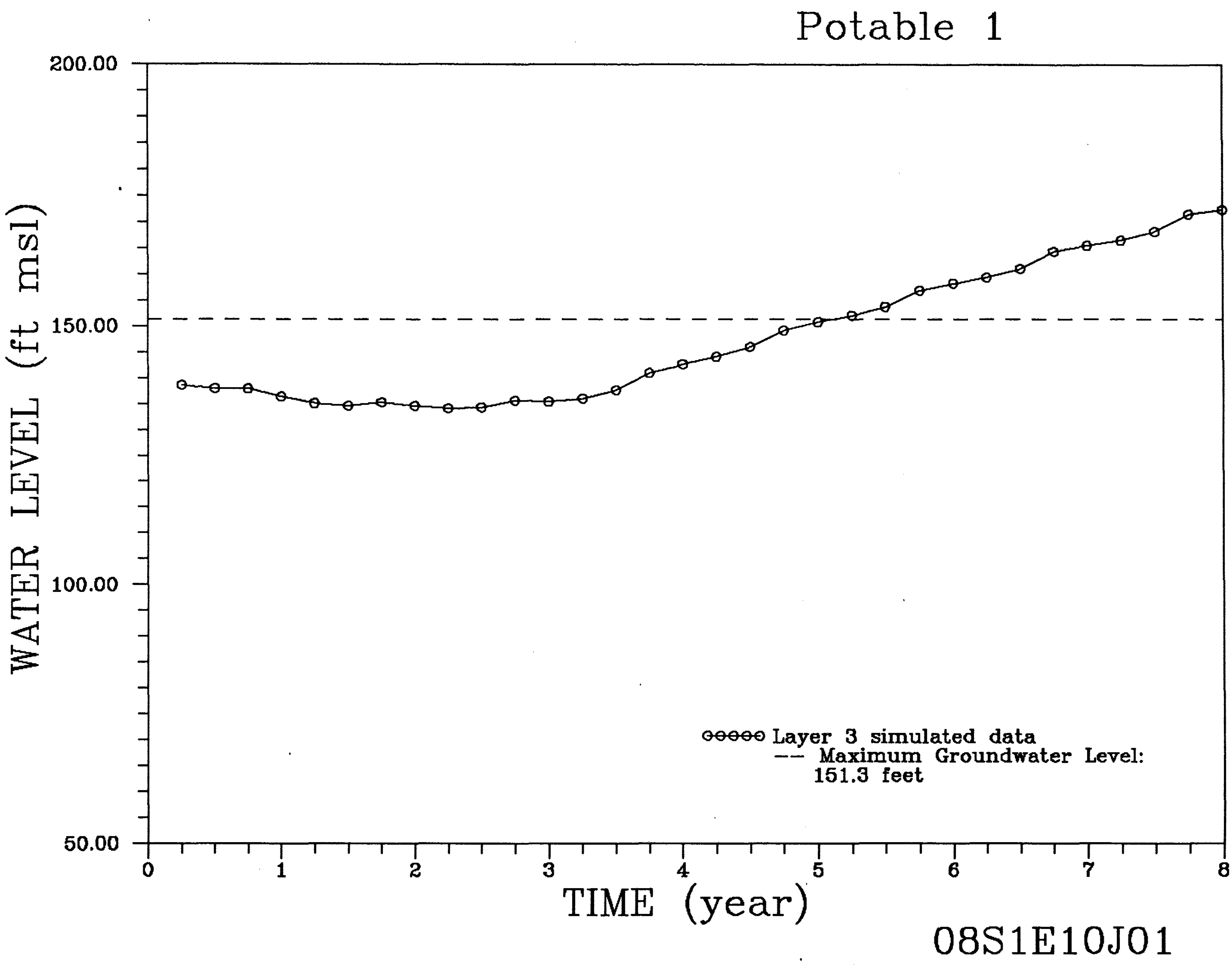

Potable 1
100.00
50.00
0.00
-50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
ooooo Layer 3 simulated data
-- Maximum Groundwater Level:
46 feet

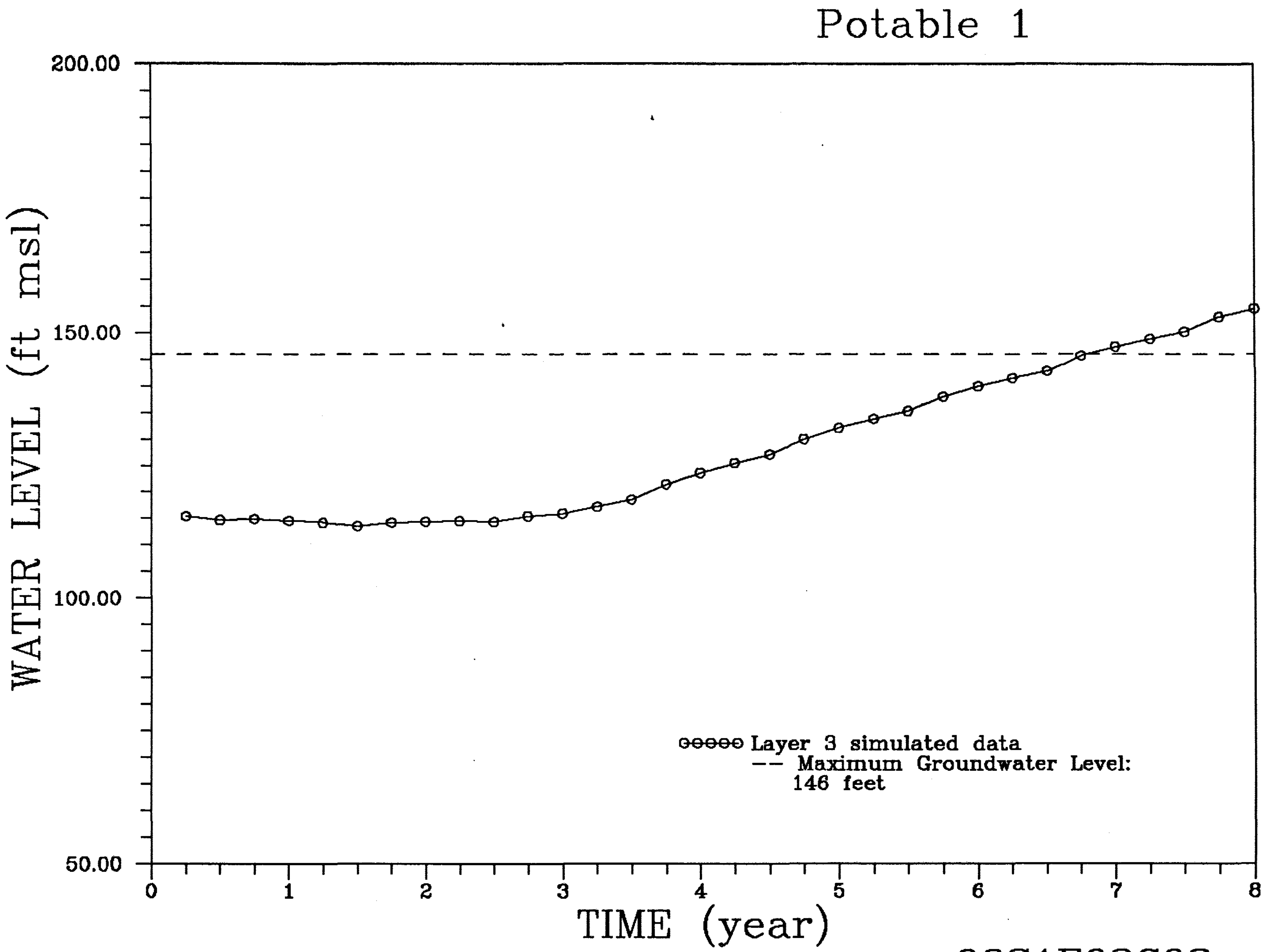
07S1W02G01

Potable 1

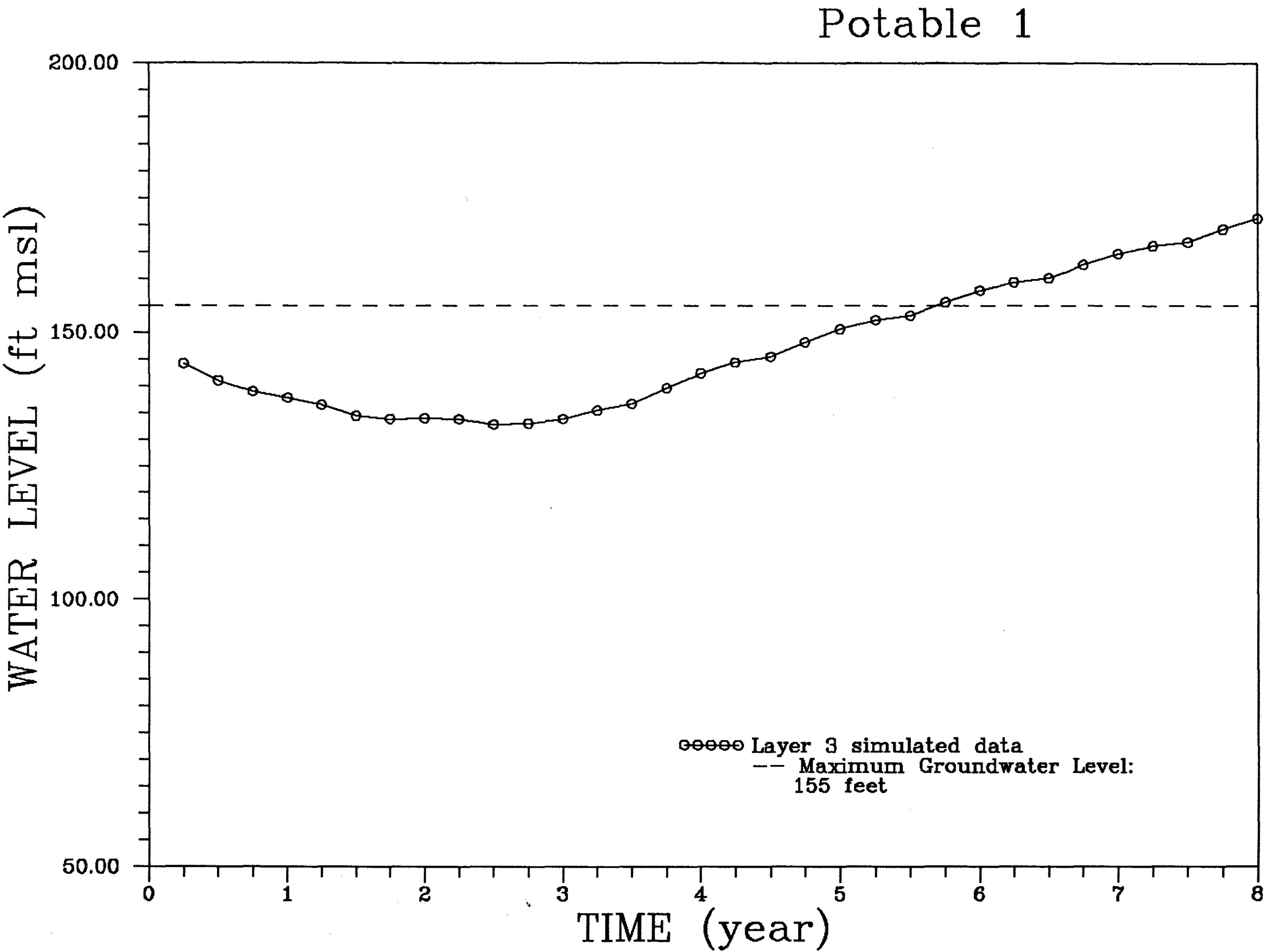


08S1E05N01

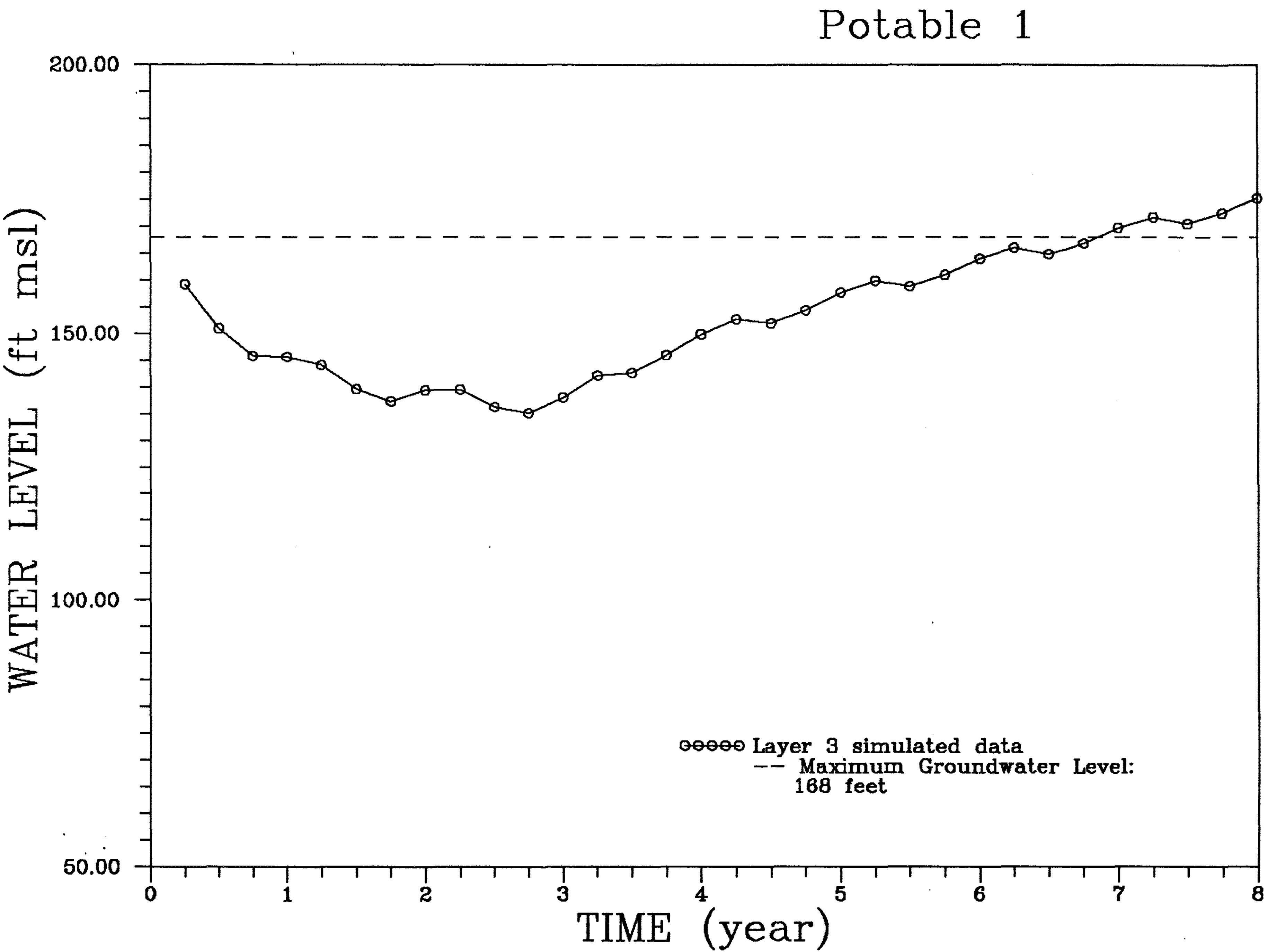

Potable 1
200.00
150.00
100.00
50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
ooooo Layer 3 simulated data
-- Maximum Groundwater Level:
151.3 feet
08S1E10J01


Potable 1
WATER LEVEL (ft msl)
200.00
150.00
100.00
50.00
0
1
2
3
4
5
6
7
8
TIME (year)
Layer 3 simulated data
-- Maximum Groundwater Level:
146 feet

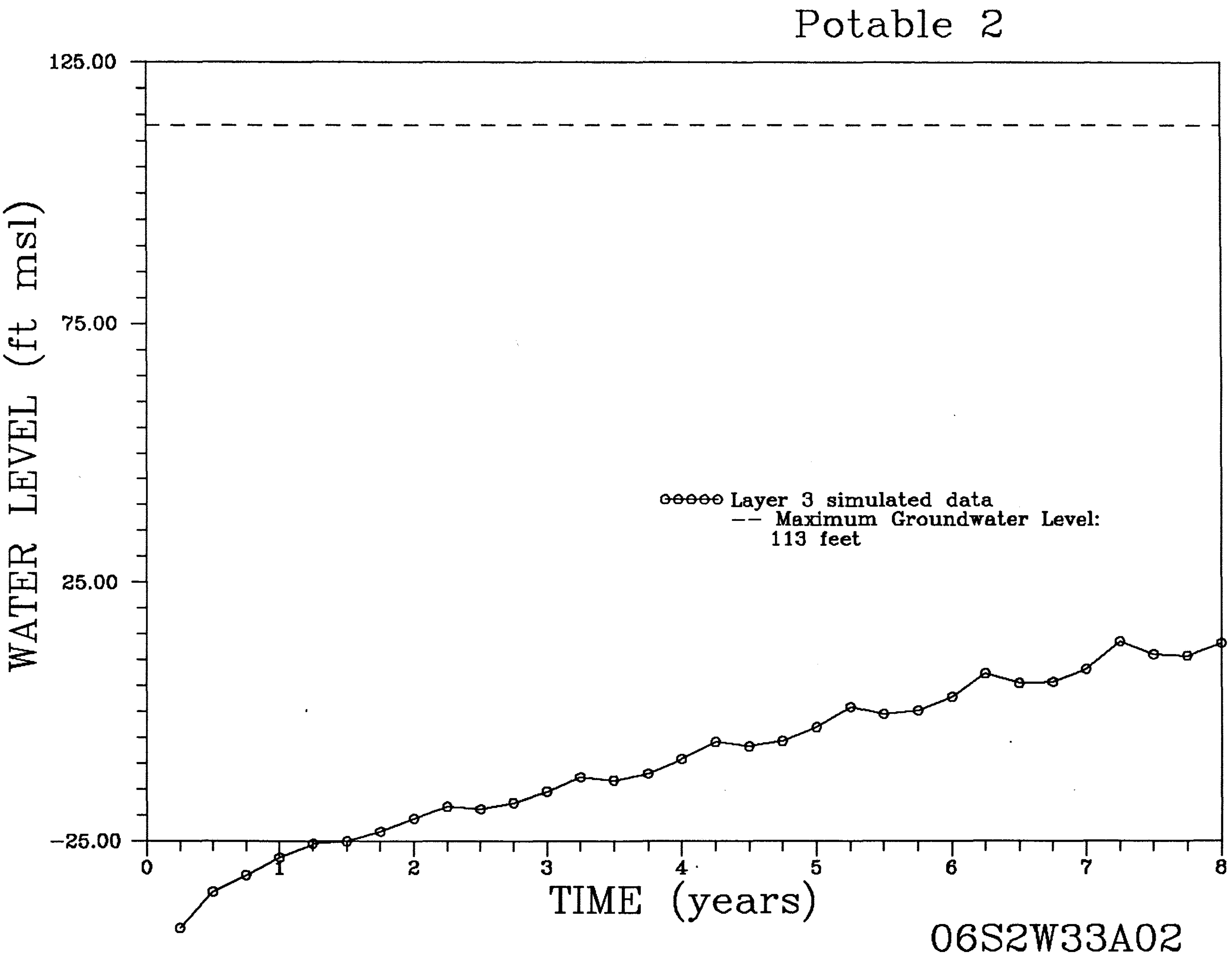
08S1E02C02

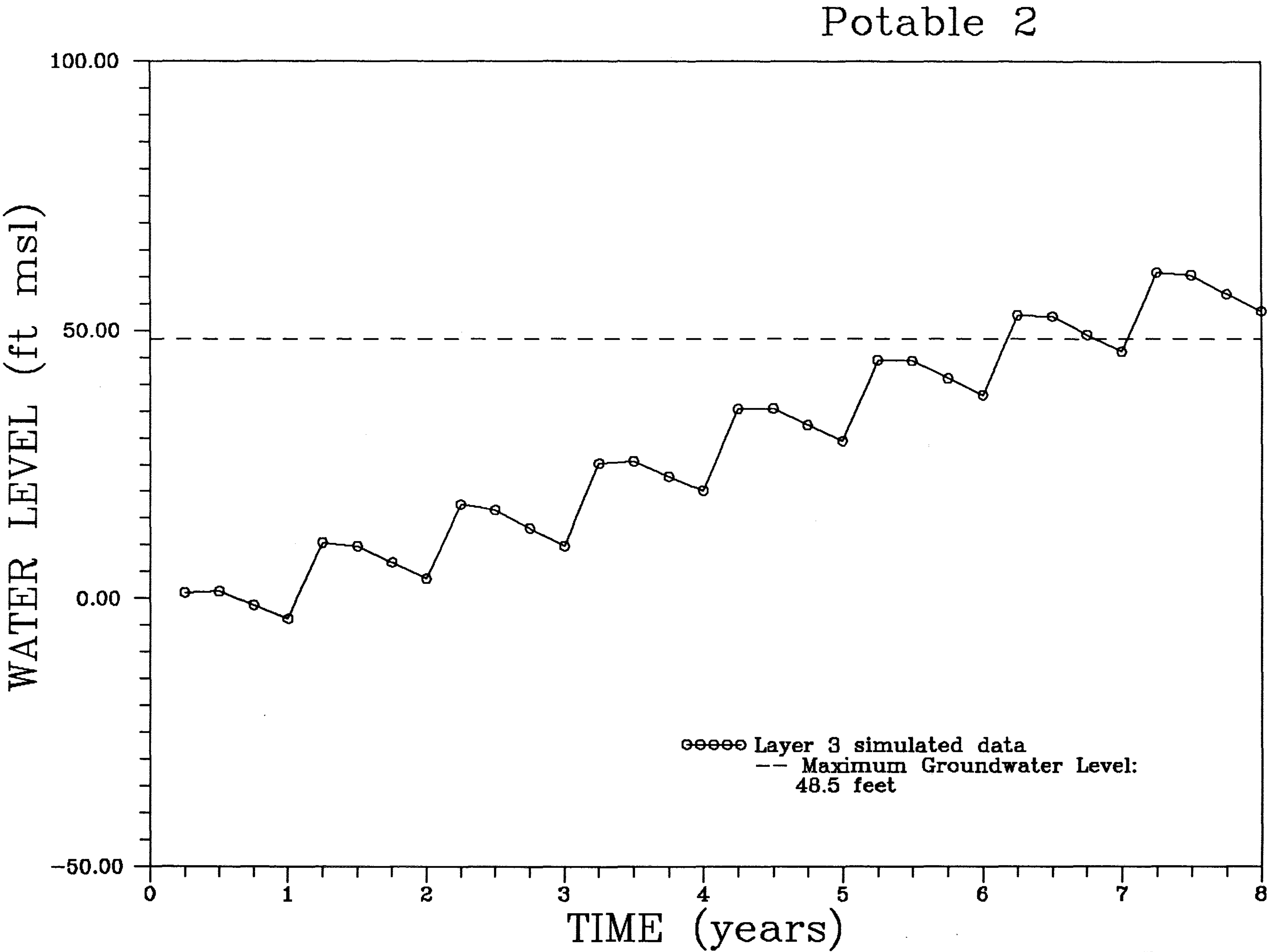

Potable 1
200.00
150.00
100.00
50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
Layer 3 simulated data
Maximum Groundwater Level:
155 feet

08S1E11Q01


Potable 1
200.00
150.00
100.00
50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
Layer 3 simulated data
Maximum Groundwater Level:
168 feet

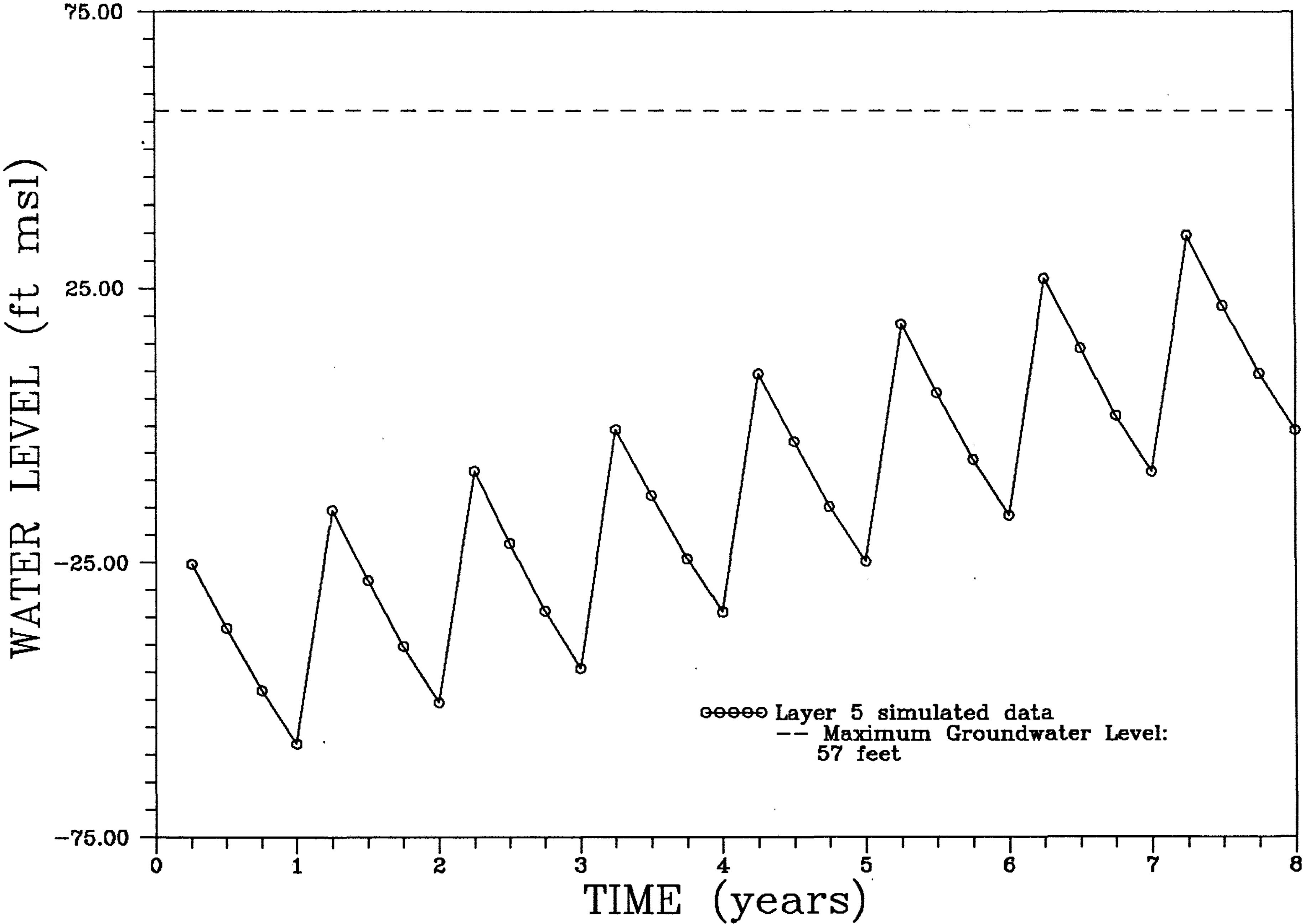
08S2E18L01


Potable 2
125.00
75.00
25.00
-25.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (years)
Layer 3 simulated data
-- Maximum Groundwater Level: 113 feet
06S2W33A02

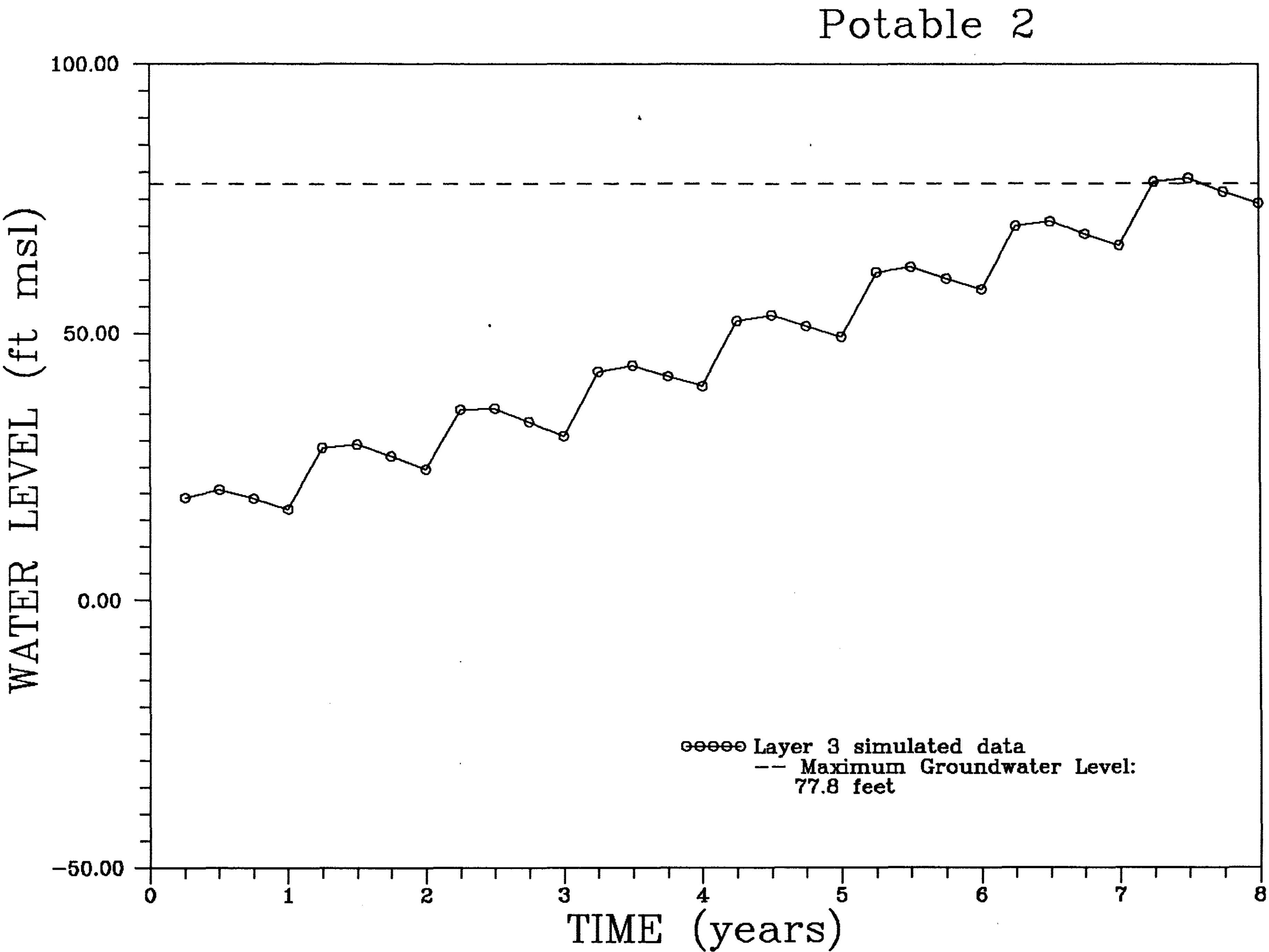

Potable 2
100.00
50.00
0.00
−50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (years)
Layer 3 simulated data
Maximum Groundwater Level:
48.5 feet

07S1E06L01

Potable 2

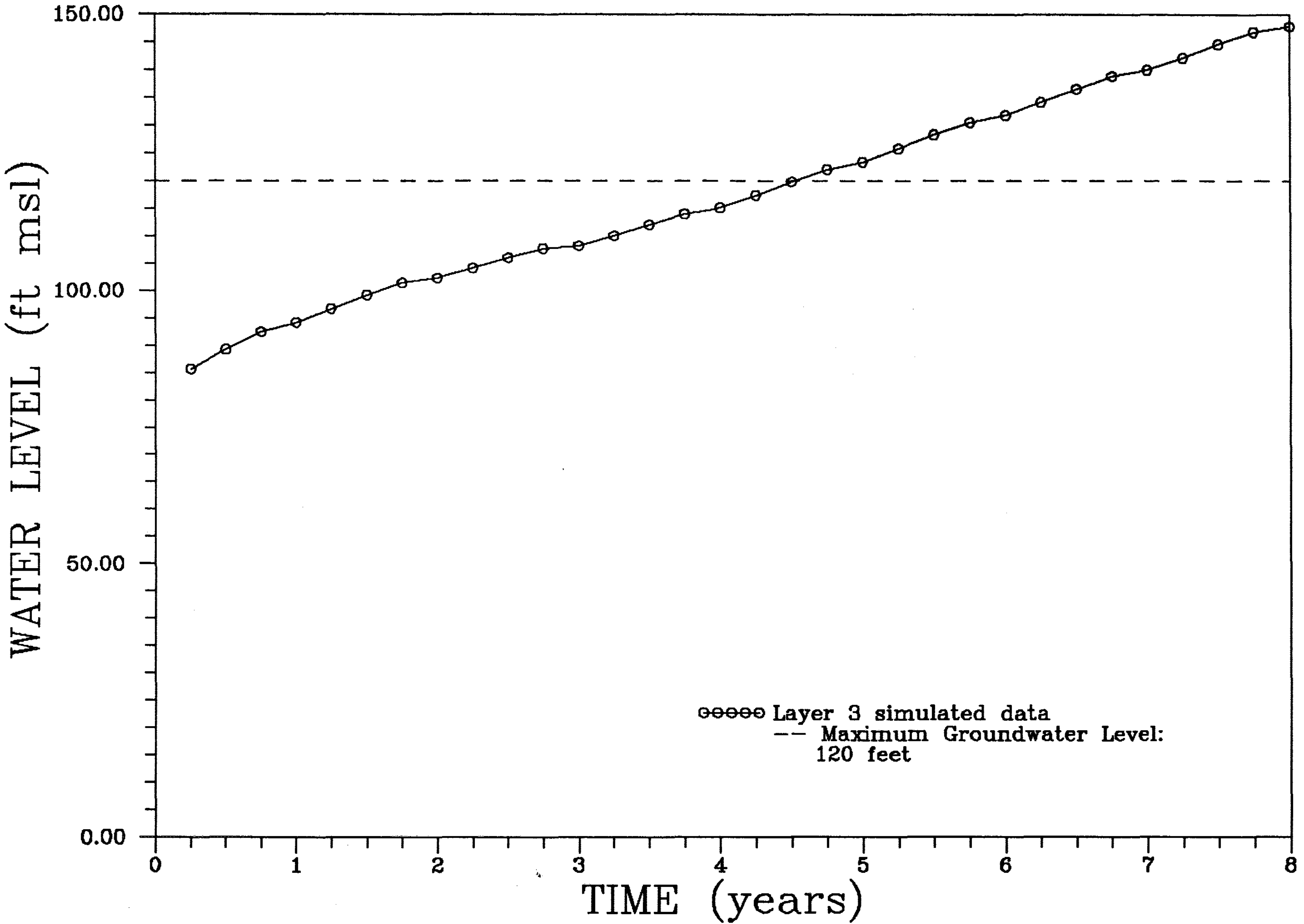


07S1E07F01


Potable 2
100.00
50.00
0.00
−50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (years)
Layer 3 simulated data
Maximum Groundwater Level:
77.8 feet

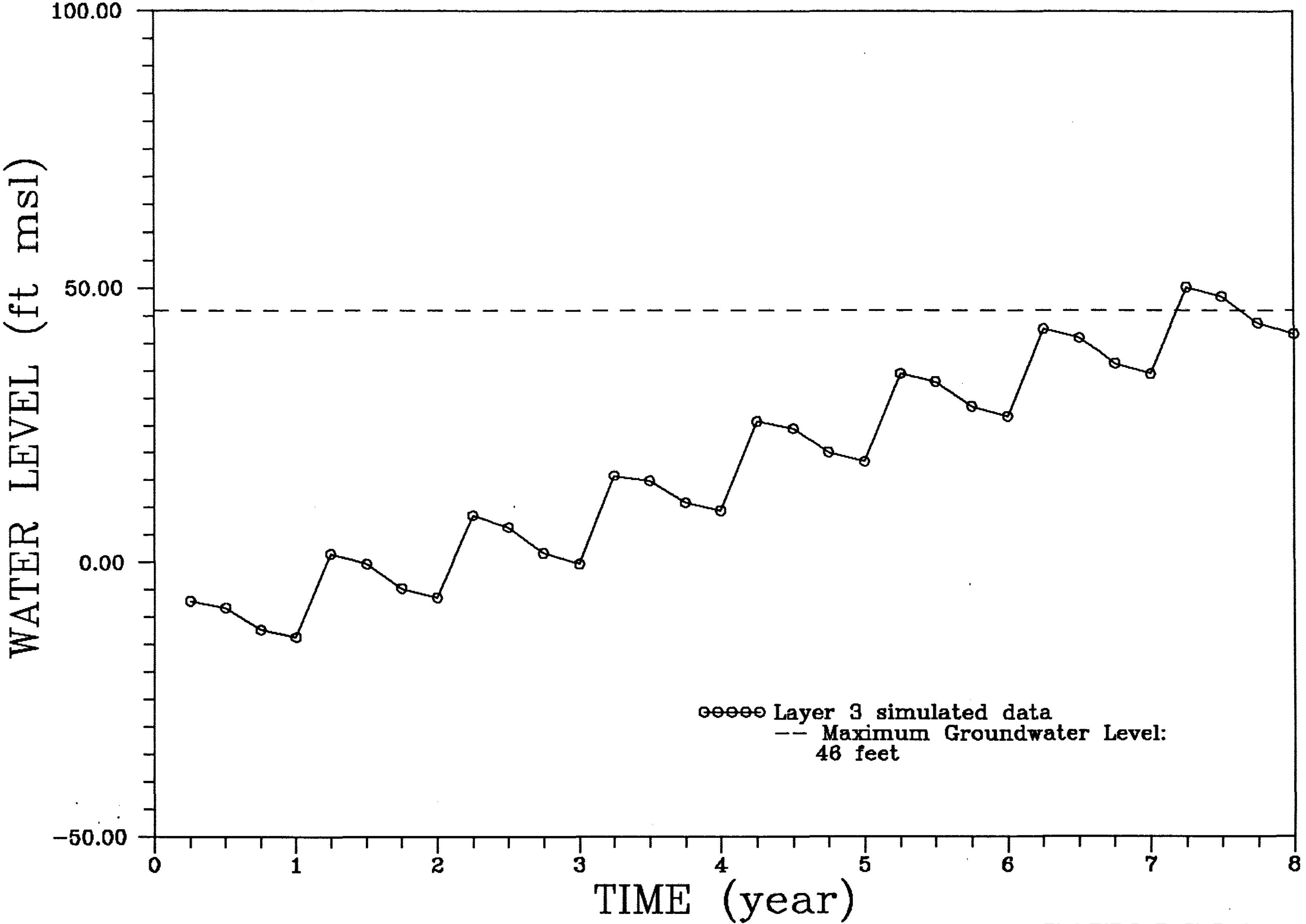
07S1E07R99

Potable 2

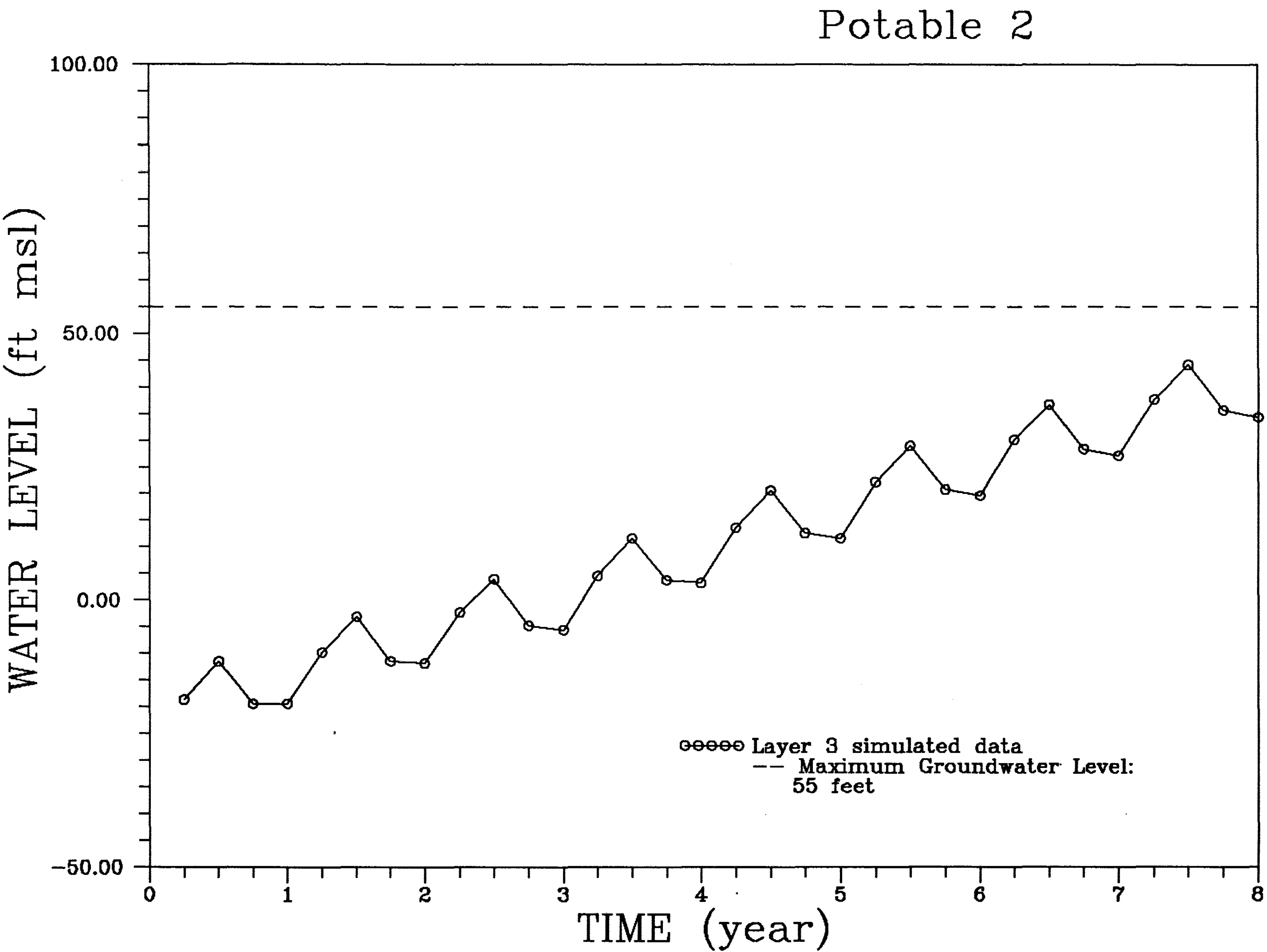


07S1E31A01

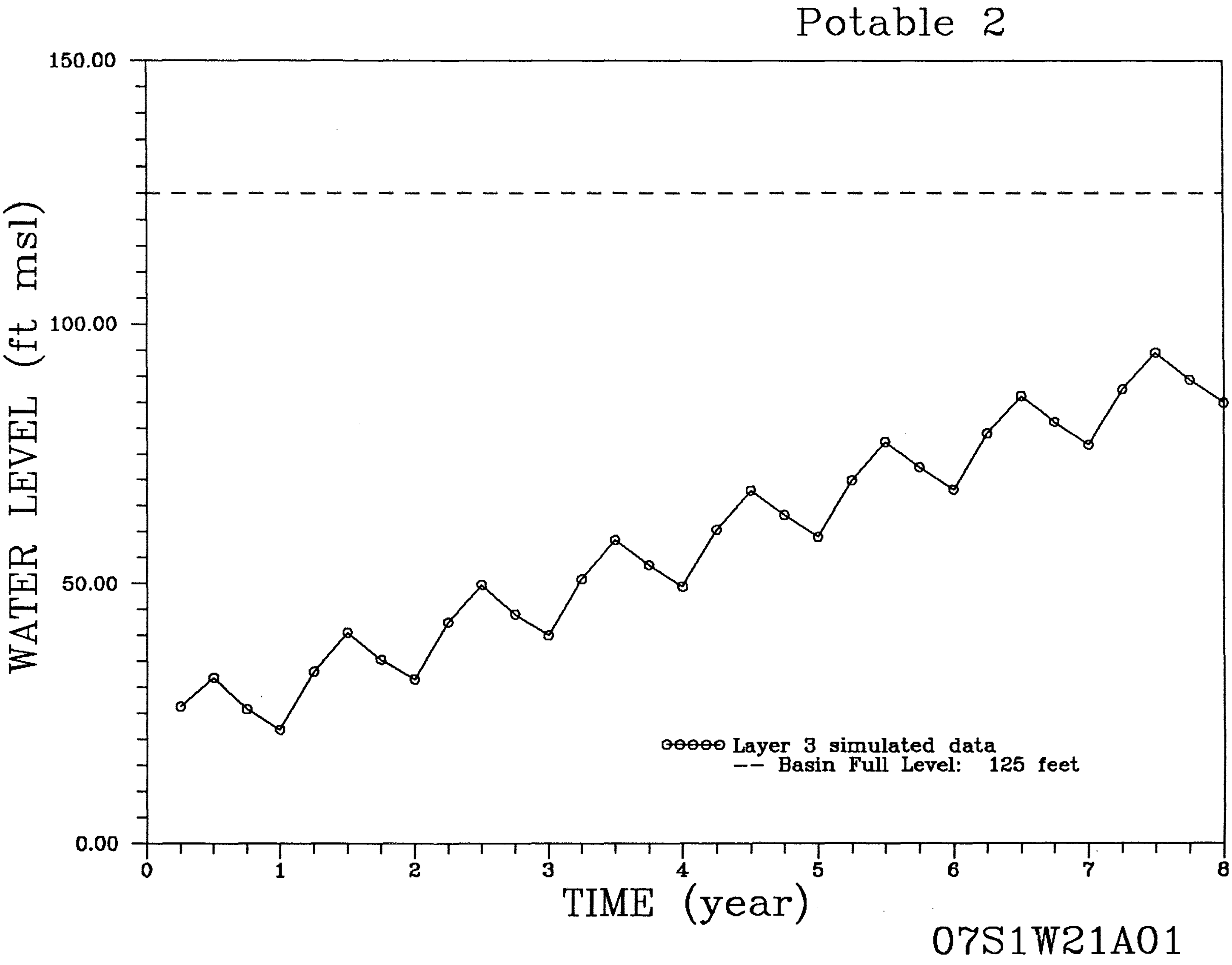
Potable 2



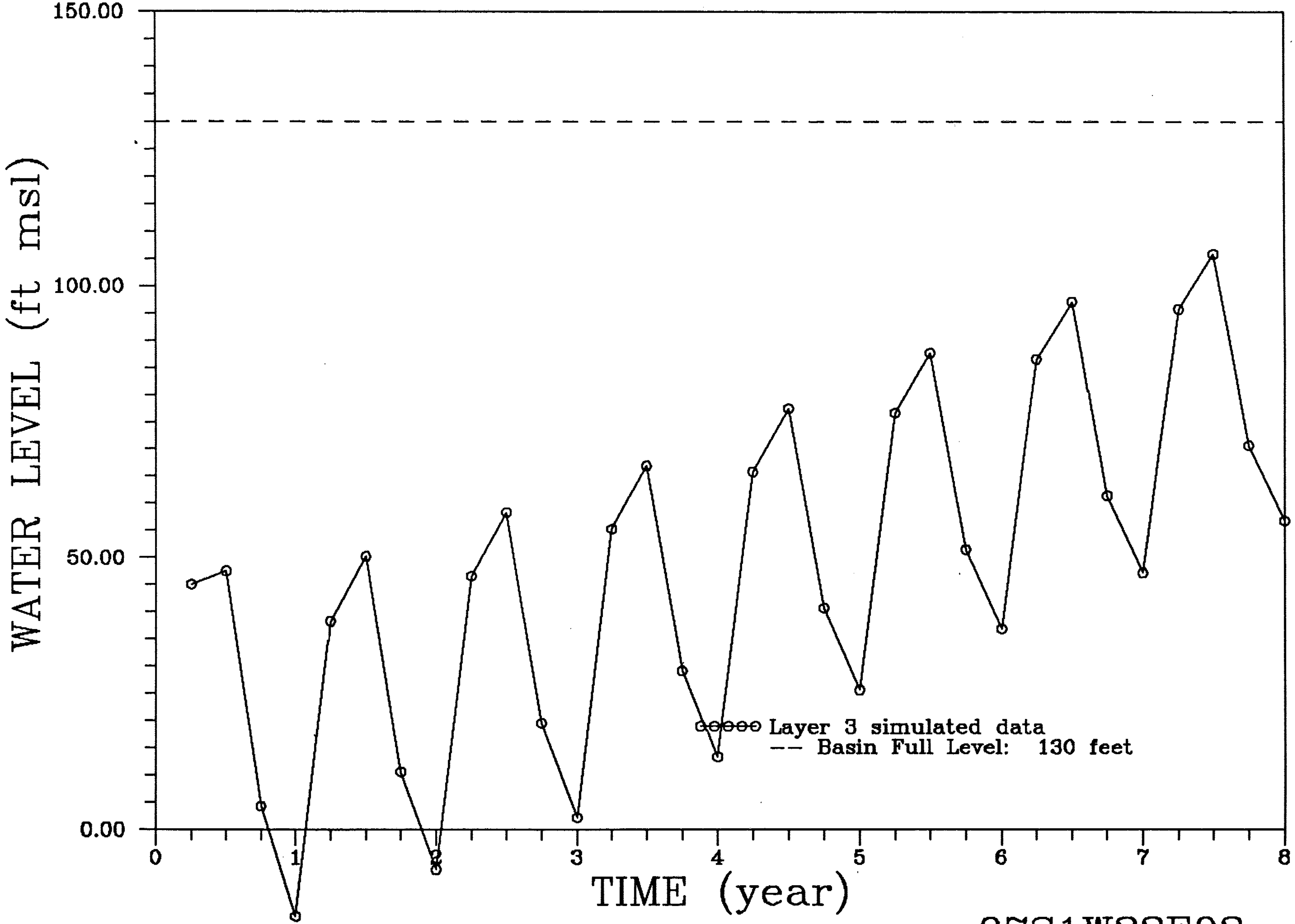
07S1W02G01


Potable 2
100.00
50.00
0.00
-50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
Layer 3 simulated data
-- Maximum Groundwater Level:
55 feet

07S1W09E02

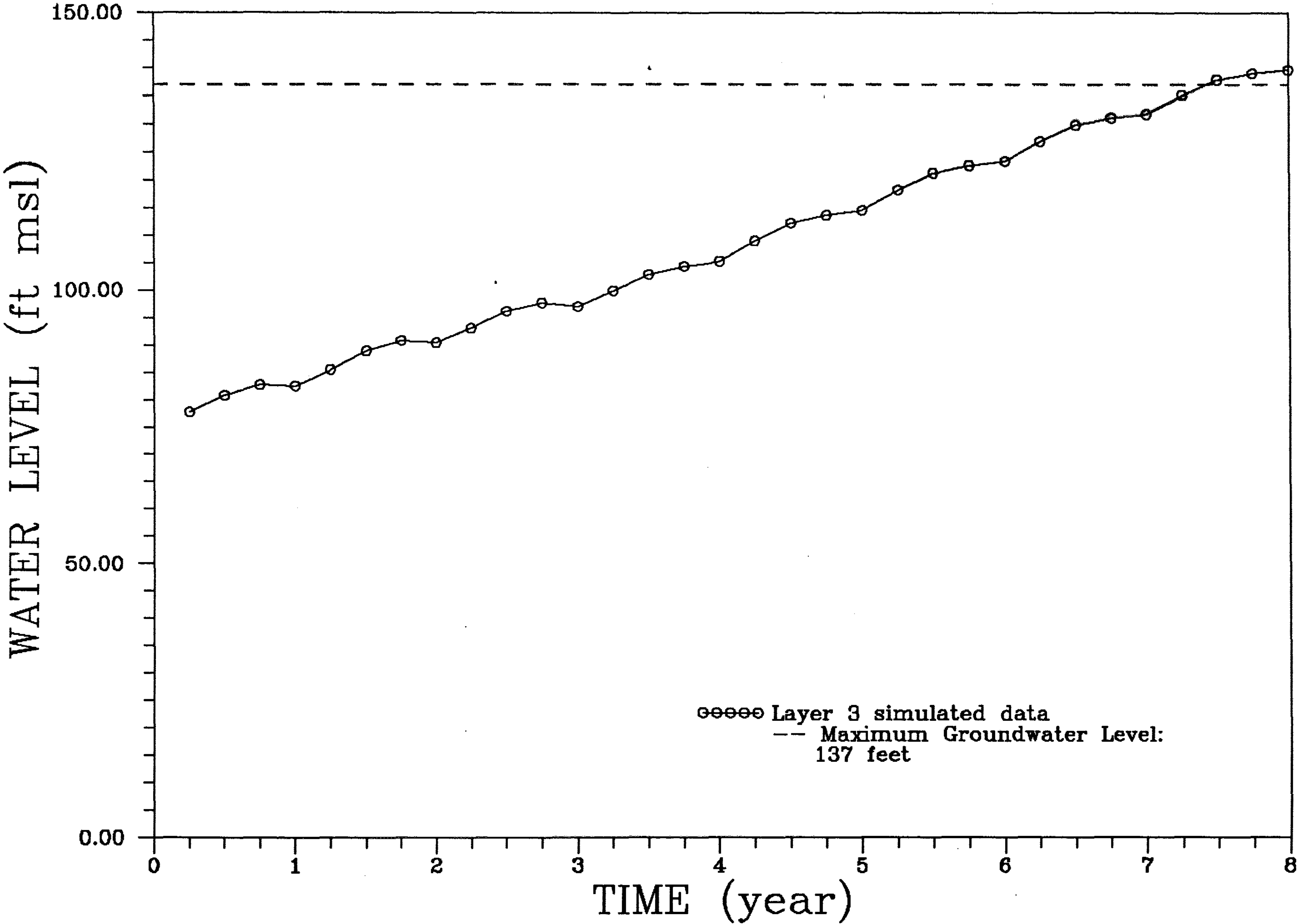

Potable 2
150.00
100.00
50.00
0.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
Layer 3 simulated data
-- Basin Full Level: 125 feet
07S1W21A01

Potable 2



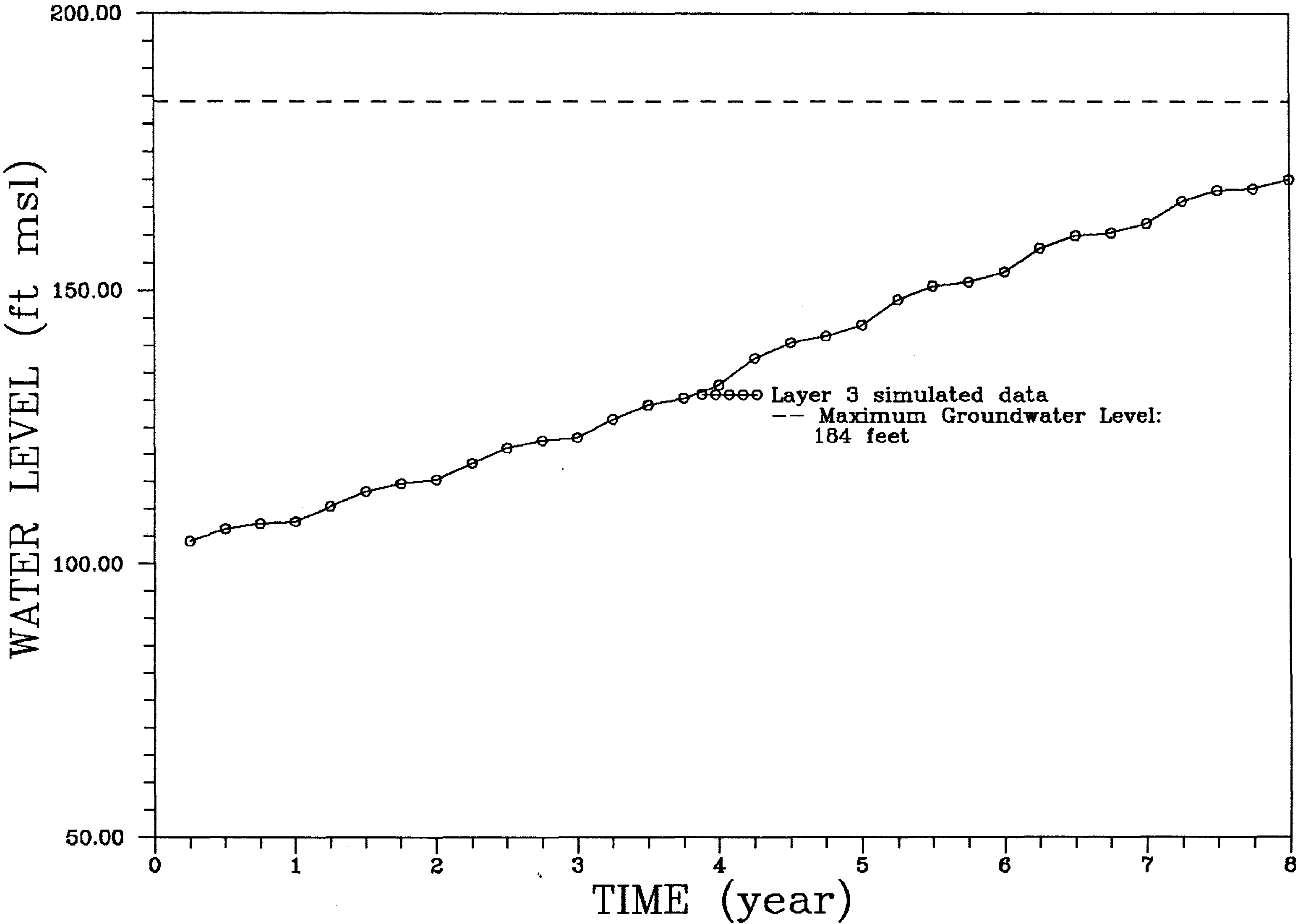
07S1W22E02

Potable 2

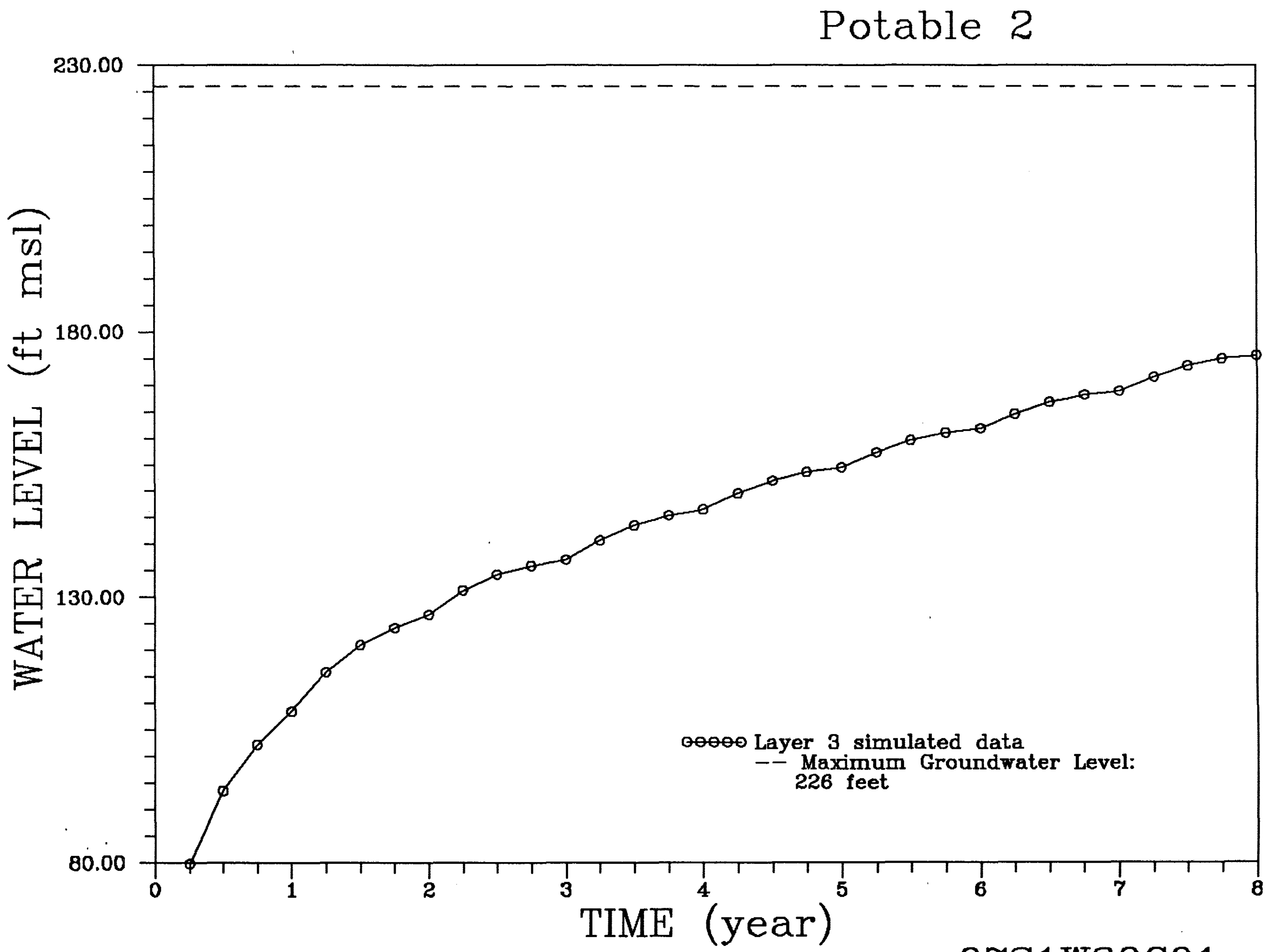


07S1W25L01

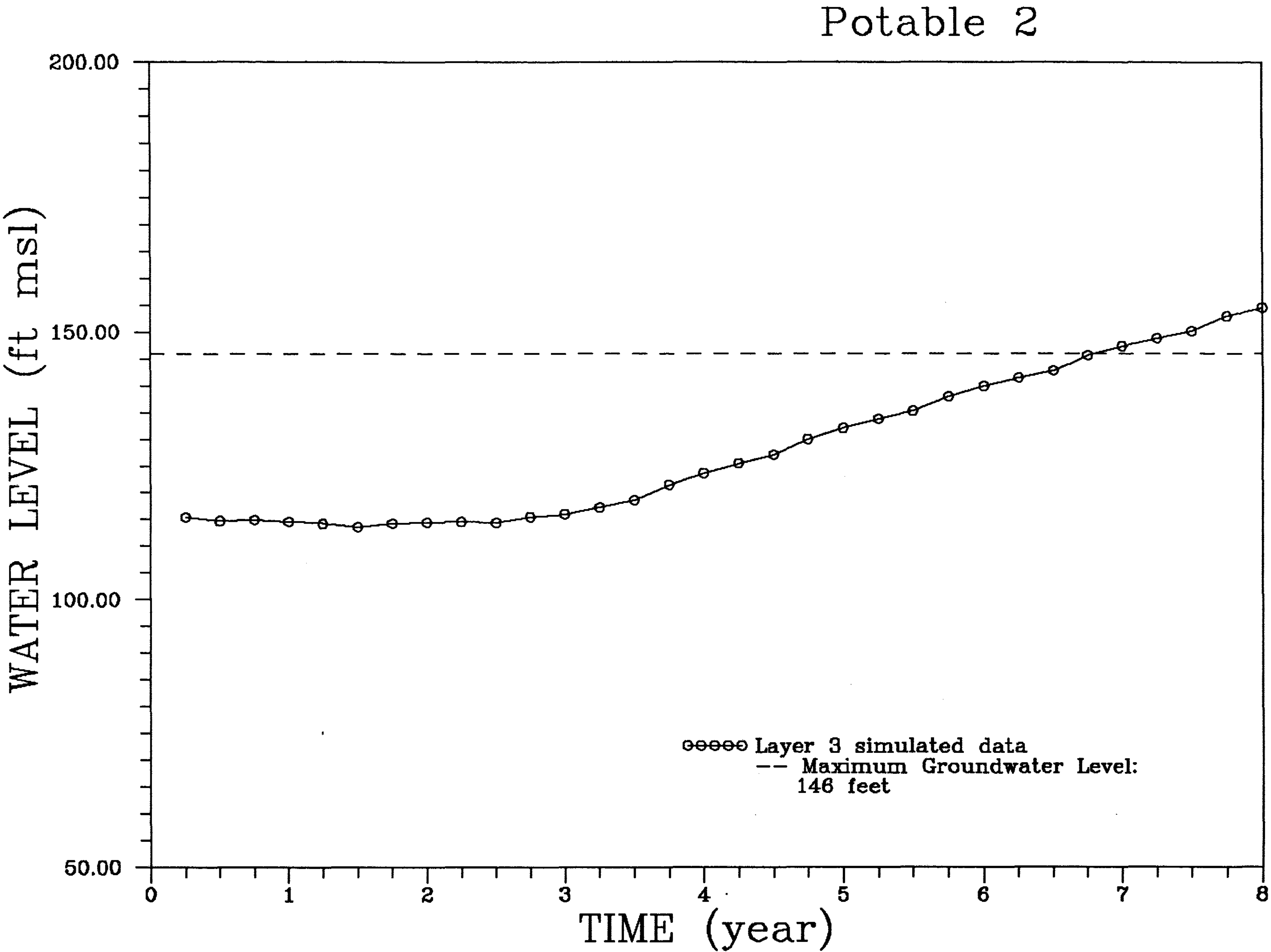
Potable 2



07S1W28R01

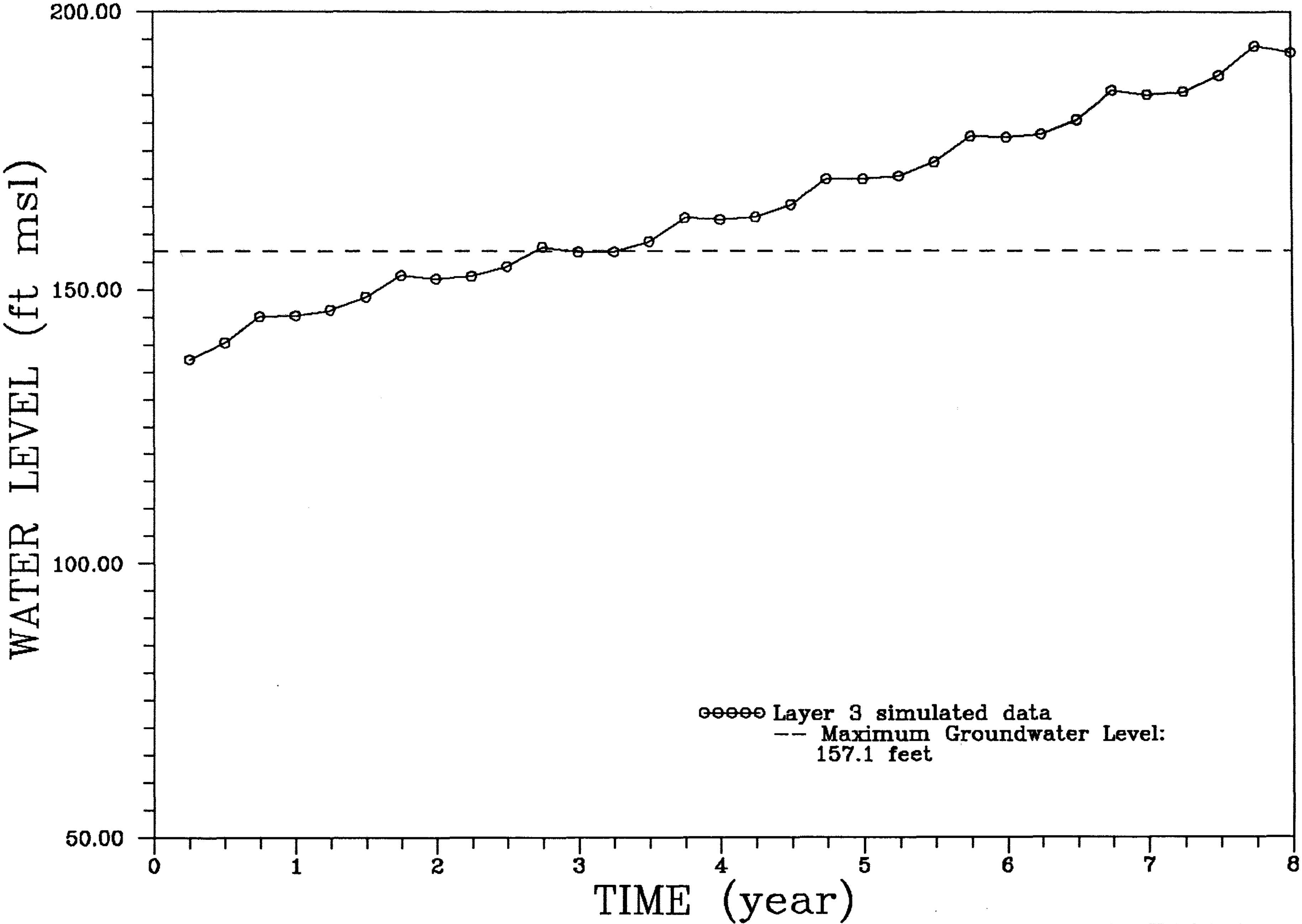

Potable 2
WATER LEVEL (ft msl)
230.00
180.00
130.00
80.00
TIME (year)
0
1
2
3
4
5
6
7
8
Layer 3 simulated data
-- Maximum Groundwater Level:
226 feet

07S1W30C01


Potable 2
200.00
150.00
100.00
50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
Layer 3 simulated data
Maximum Groundwater Level:
146 feet

08S1E02C02

Potable 2



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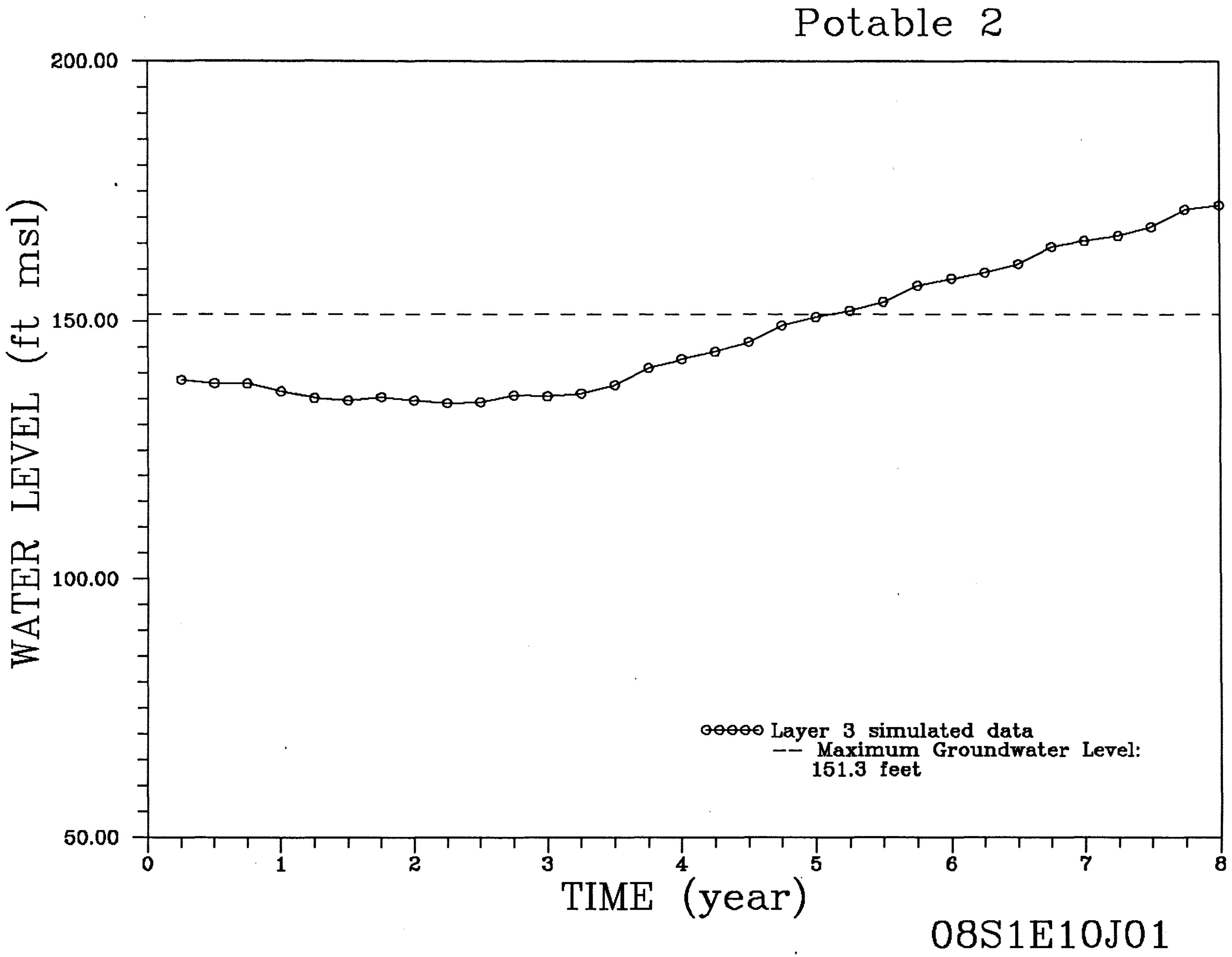
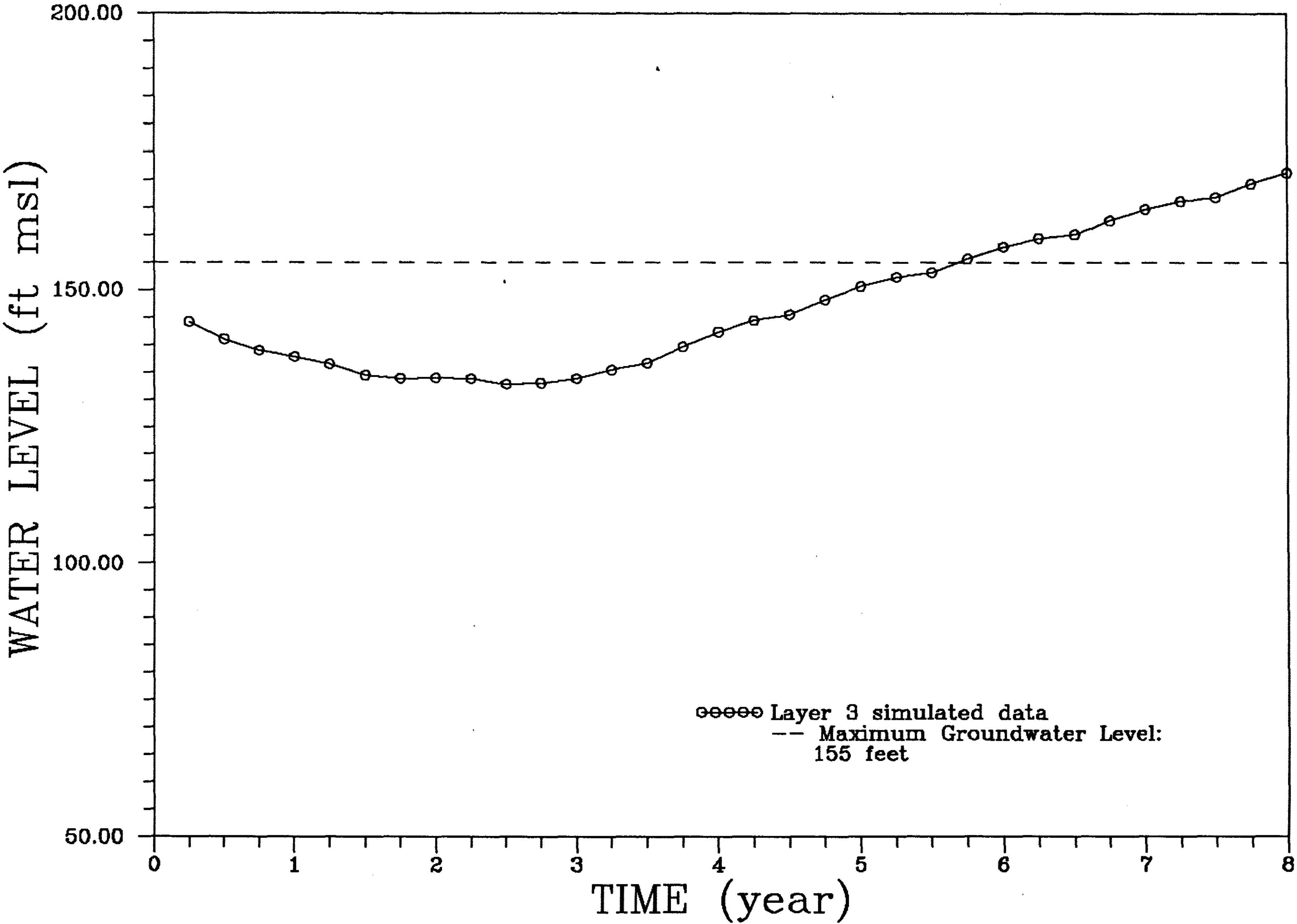
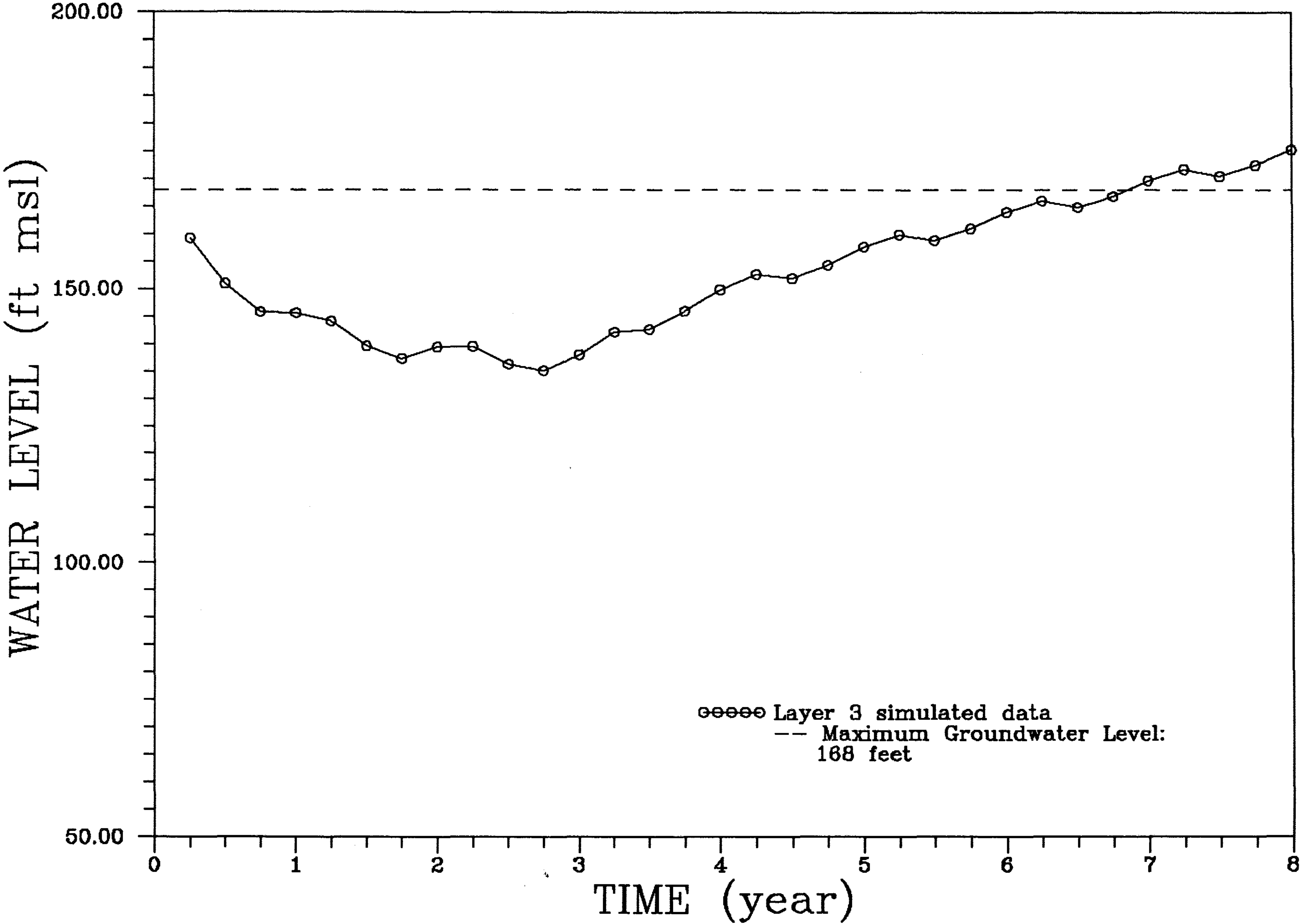

Potable 2
200.00
150.00
100.00
50.00
WATER LEVEL (ft msl)
0
1
2
3
4
5
6
7
8
TIME (year)
ooooo Layer 3 simulated data
-- Maximum Groundwater Level:
151.3 feet
08S1E10J01

Potable 2



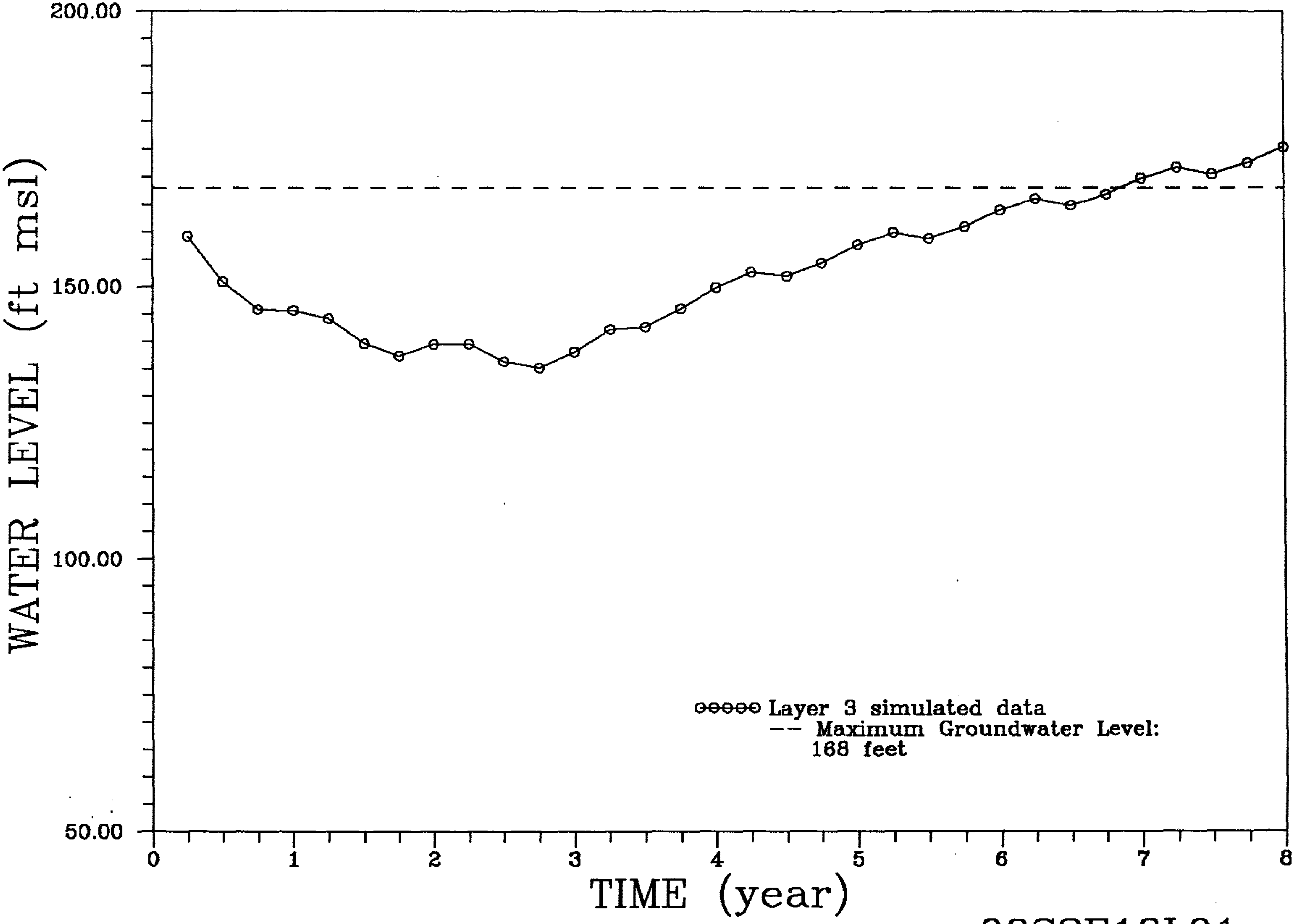
08S1E11Q01

Potable 2



08S2E18L01

Potable 2



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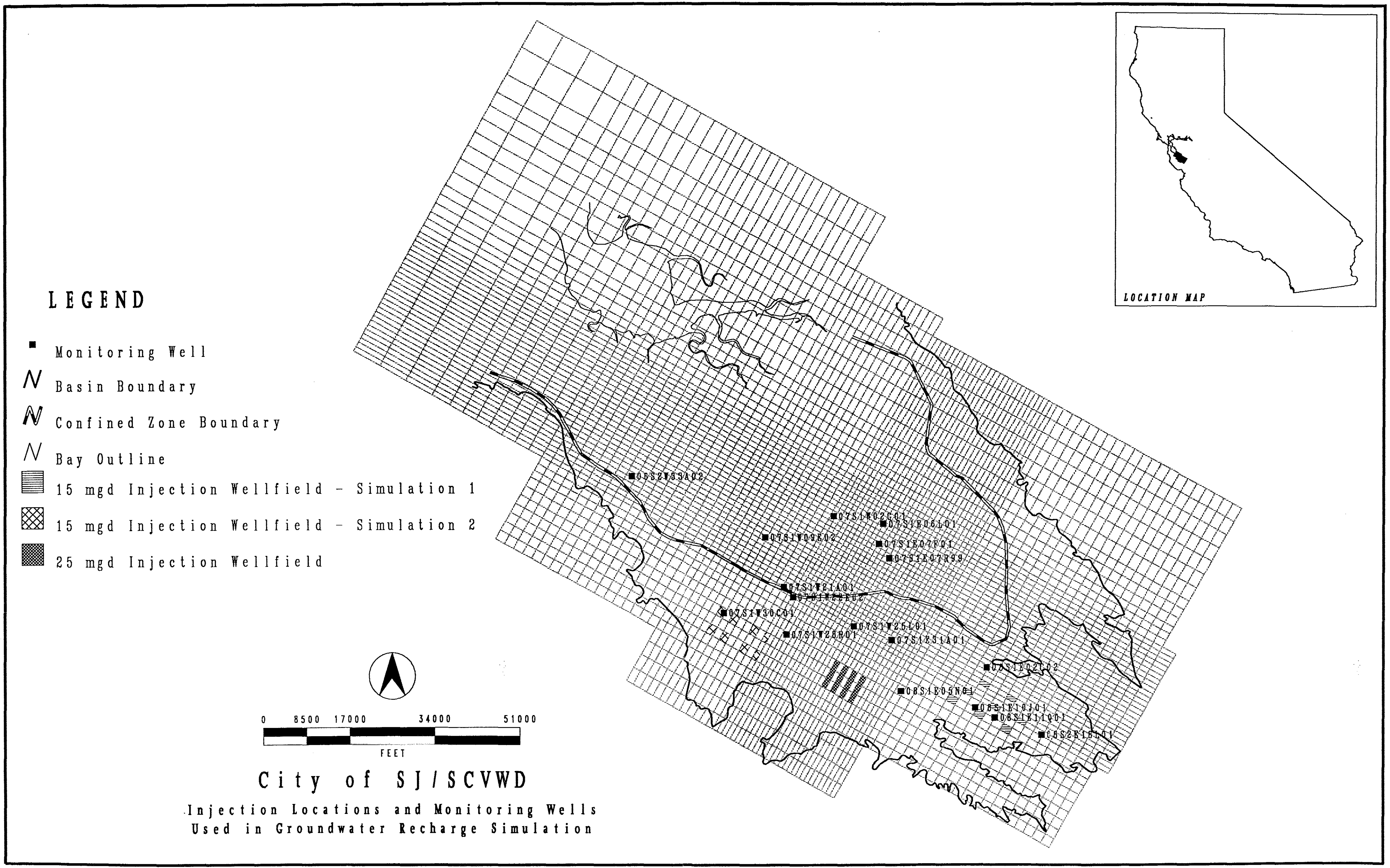

City of SJ/SCVWD

Injection Locations and Monitoring Wells Used in Groundwater Recharge Simulation

P230.AML

August 06, 1992